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(Recognosce notum, ignotum inspice)

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PRESIDENTIAL ADDRESS

MYCOLOGY AND THE WAR

By G. SMITH, M.Sc., F.R.I.C.

It is my privilege to present this address under far happier circumstances than have obtained at several previous Annual Meetings. Although there is still fighting and unrest in many parts of the world, the major war is over and we can now look forward to a gradual improvement in general conditions and, I hope, to an era of steady progress. I have chosen as my subject 'Mycology and the War' because I think it will be useful at this stage to review the past six years from two aspects, the effect of the war on the study of mycology, and the contribution which mycology has been able to make to the war effort.

Although I may claim to be interested in all aspects of mycology, my knowledge is very limited, except perhaps in one specialized field, and I cannot therefore hope to present a picture complete in detail. If, then, I do less than justice to the efforts of some members of the mycological fraternity, it is entirely because I am unable to speak with authority about some of the important war-time activities, and not with any desire to belittle work done in other fields.

When war broke out in September 1939, the prospect for this Society looked decidedly bleak. It was soon evident that this was to be a war of physicists, just as the first World War was a conflict between chemists, and mycologists either simply did not come into the ken of Government officials or were regarded as rare species of the category usually labelled 'suspicious'. The first effect of the war was the cancellation of the programme of autumn forays, and it certainly seemed that any idea of serious field work would have to be abandoned until after the cessation of hostilities. During the first two years there were no official forays and in 1941 there was only a single-day foray at Epping. This was described at the time as a 'token foray', being held, in spite of difficulties, in order to keep alive, though only just alive, one important side of the Society's activities. In the following autumn the two-day foray at the Royal Holloway College was a little more ambitious but still compared very unfavourably with pre-war arrangements. But then came a change, the primary impulse for which was food-rationing. The British public, aided and abetted by a number of more knowledgeable refugees, slowly woke up to the fact that the cultivated mushroom, displayed in the shops at fantastic prices, did not constitute the only means of lending attractiveness to otherwise monotonous dishes, but that there was a wealth of equally attractive food to be had for the picking. Displays of edible and poisonous fungi at South

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Kensington during the seasons of 1941–3, and at the autumn shows of the Royal Horticultural Society from 1942 onwards, attracted greater attention each succeeding year. Lectures by Dr Ramsbottom in the South Kensington Museum, which were somewhat sparsely attended in their first season in 1942, drew audiences of continually increasing size, and Women's Institutes all over the country asked for lectures and demonstrations. At the end of 1942 the Foray Committee was set up, with the result that foray programmes, if not the forays themselves, became more ambitious.

The main interest in all this activity, so far as this Society is concerned, is that many, who first began to notice fungi for their possible edible qualities, soon began to desire further, and less utilitarian, knowledge. For many years there has been a great need for more naturalists interested in fungi. There are many points concerning the larger fungi about which we require far more information than is available at present, and this knowledge can best be acquired by large-scale observation. Now that the public is becoming fungus-conscious I do not think it is too much to hope that some of the converts will retain their interest, improve their knowledge and follow in the steps of the distinguished amateurs who have contributed so much to this branch of mycology. In the meantime, the point I wish to emphasize is that the present widespread interest in the larger fungi is directly attributable to the effects of the war, first in creating conditions in which the desire for edible novelties outweighed the traditional British suspicion of all toadstools and, secondly, in bringing into our midst a sufficient leaven of Europeans accustomed to regard many of the despised toadstools as good and valuable food.

Regarding the effect of the war on another important branch of mycology, phytopathology, I think there is little doubt that the science has benefited in several ways from the national drive for enormously increased production of foodstuffs. It was to be expected that more intensive cropping would result in a serious increase in the incidence of disease but, actually, there have been comparatively few unusual outbreaks. The main reason for this immunity is that a long educational campaign by our Research Stations and Advisory Services bore fruit during a period of national emergency. Control measures, such as proper rotation of crops, seed dressing with standardized organo-mercurial preparations, soil sterilization in glass-houses and the use of fungicidal sprays, have all been widely practised as never before. The farmer has come to appreciate, far more than he did before the war, the services which the phytopathologist can render. Once convinced that the scientist can be of real assistance, the agriculturalist himself becomes more scientifically minded and can, in his turn, greatly assist the professional scientist.

The great body of amateurs—gardeners and allotment-holders—have responded to the appeal for bigger and healthier crops in no uncertain fashion. The Advisory Services have been gratified, but also decidedly embarrassed, by the volume of requests by private growers for advice and assistance, and thousands who had never used a spray before have acquired and studied the literature issued by the Ministry of Agriculture and made a determined effort to control pests and diseases. As far as I can

judge, the majority of amateurs are as yet more insect-conscious than fungus-conscious, but this is, I think, quite natural. Perhaps the most serious lapse has been the reluctance to take prophylactic measures against potato blight, sometimes with disastrous results. Also there has been, during the present season a fairly bad epidemic of brown rot of apples, due to *Sclerotinia fructigena*. However, many gardeners are now enquiring what can be done to safeguard the precious apples and it will need very little to convince those who have already found the value of insecticides that the control of diseases is also well worth while.

It is when we come to review the state of industrial mycology during the war that we see the most dramatic development. The two major factors influencing this progress were the spread of the war to the Far East and the resumption of interest in penicillin. Before discussing these, however, I ought to mention one other way in which mycology has been of benefit during the war, namely the development of large-scale production of food-yeast.

It has long been known that the yeast, *Torulopsis utilis*, can synthesize protein from carbohydrate and inorganic sources of nitrogen. The yeast is palatable, much more so than bakers' yeast, the protein it contains is of high biological value, and it is, as well, an excellent source of the B group of vitamins. During the first World War food-yeast was manufactured for human consumption in Germany and again, during the late war, it was made on a large scale, although the only available source of carbohydrate was wood sugar made by a costly process. In this country it has never been made on a large scale. Plans were made, early in the war, to manufacture fairly large quantities from molasses, but this scheme was abandoned because of the difficulty of finding shipping for the raw material. However, after successful semi-large scale experiments had been carried out in England, it was eventually decided to start manufacture in the sugar-producing Colonies, with the double object of finding new uses for sugar against the time when production should once again be in excess of demand, and, in the meantime, of correcting a serious degree of undernourishment amongst large sections of the population in the sugar-growing areas. A company called 'Food Yeast Ltd.' was formed by the Ministry of Food, and Jamaica was chosen for the first large scale venture.

The English pilot experiments were carried out by Thaysen at Teddington and a most interesting stage in the development was the production, by artificially induced mutation, of two new varieties of *Torulopsis utilis*. The first of these, variety *major*, is characterized by its production of cells approximately twice the size of those of the parent strain. The second new strain, variety *thermophila*, is of special value for countries with a high prevailing temperature. During the large scale fermentation much heat is evolved and, unless cooling water of sufficiently low temperature is available, both *T. utilis* and var. *major* are inhibited, their optimum temperature being about 30° C. The new variety *thermophila* grows well at 39° C., permitting the use of cooling water with a temperature as high as 30° C.

The war in the Far East, at an early stage, brought realization to many

of the appalling damage which fungi are capable of doing when they find their ideal environment. Before the war every mycologist knew that the main essential for rapid growth of fungi, and especially of moulds, is abundant moisture, and it was no surprise when information reached this country in 1942 that the destruction of military equipment was on an alarming scale. It has been estimated that, in the early stages of the campaign, less than 50 % of all equipment arrived in usable condition, and some commanders have stated that they considered themselves fortunate if 15 % reached them undamaged. Not all of the damage, of course, was due to the ravages of moulds. Flimsy and unsuitable packing accounted for a large share of the wastage, especially in the beginning, but, as time went on, a larger and larger proportion could be attributed to the activities of moulds and the physico-chemical effects of very high atmospheric humidity.

For many years before the war, some of our greatest industries which manufacture goods for export had been alive to the necessity for protecting materials against mould attack, and valuable work had been done, particularly by the British Cotton Industry Research Association, in defining conditions necessary for growth of moulds and in finding suitable antiseptics. But storage of bales of cotton goods in Indian go-downs in peace time, severe test though it is, is not half so bad as storing military equipment in improvised shelters in tropical forest, where the temperature is very near to the optimum for growth of moulds and the relative humidity is over 90 %, and even close to 100 %, for considerable periods. It is not surprising, therefore, that methods of proofing which were good enough during the era of normal trade should require drastic modification to fulfil war-time requirements.

In the spring of 1943 the Ministry of Supply somewhat belatedly realized that, if our armies were to be suitably equipped for the coming offensive, the mould problem would require some attention. The London School of Hygiene and Tropical Medicine was asked to co-operate and experiments were started in May 1943, although it was nearly another year before some branches of the Services began to realize that there was a problem. After that the volume of work increased to such an extent that it had to be shared between several different establishments. Work along the same lines was also started, almost simultaneously, in Australia and America, and, in order to prevent undue overlapping, there has been, from the beginning, free interchange of information between all three countries. Since I have been directly concerned with this work from the beginning, and as it has had little publicity up to the present, I trust that it will be of interest if I describe it in some detail.

A small chamber was fitted up, in which equipment could be exposed to atmospheric conditions similar to those of a tropical jungle at its worst. The day temperature was fixed at 95° F. at first, but was later lowered to 85° F., and the relative humidity maintained at 98 to 100 %. At night the temperature was allowed to fall, resulting in supersaturation of the air and then condensation of a film of moisture on everything inside the chamber. In the beginning, equipment put in the chamber for test was inoculated with a number of species of moulds, but very soon there was sufficient

mould on many of the specimens, and also on the shelves and the linoleum covered floor, to provide a natural reservoir of infection. Conditions in the chamber were, in some ways, more severe than those of most areas in the war zone, but, on the other hand, there were lacking the typical vegetation and the teeming insect population of tropical jungle.

Besides the testing of complete items of equipment and large samples of materials, the work involved testing hundreds of small samples of an enormous variety of products, and, in addition, the evaluation of many volatile antiseptics and fungicides. For these purposes miniature forcing houses were used, in the shape of vacuum desiccators containing water to maintain a saturated atmosphere. These were incubated in a constant temperature room at 30° C. (85° F.) and materials for test were always inoculated. In both the large tropic chamber and the small glass vessels growth of moulds on susceptible materials was extremely rapid and, after a number of trials with different incubation periods, it was decided to regard as satisfactory any equipment which would remain substantially free from mould for four weeks under these conditions.

For inoculation of specimens it was not easy to make the ideal selection of suitable species but, eventually, six species of moulds were used, and these have been widely distributed to other institutions assisting with the work. The species were *Aspergillus niger* and *A. amstelodami*, both found frequently on mouldy equipment in the tropics and nearly omnivorous; *Penicillium brevi-compactum*, almost as widely occurring; *Paecilomyces varioti*, whose special predilection seems to be bakelite; and two cellulose destroyers, *Chaetomium globosum* and *Stachybotrys atra*. There have been a few surprises in the flora which eventually appeared on some materials, a flora sometimes entirely different from the inoculum. In the early days *Paecilomyces* was not used as a deliberate infection, but it appeared so persistently on samples of sheet bakelite that it was eventually added to the list of test organisms. On one or two occasions *Memnoniella echinata*, described by Bisby, just about the same time, as a 'suspiciously rare fungus', appeared in pure culture, completely covering large sheets of cellulosic material. Several times vigorous growths of *Trichoderma viride* have occurred, particularly on jute fabrics. In general, however, the most common infections recovered from incubated specimens other than fabrics have been the two species of *Aspergillus* and, somewhat less frequently, of *Penicillium*.

I do not intend to catalogue all the various materials which have been tested and for which means of protection have had to be found. They include almost every item of dress, bedding, shelter, weapons and means of communication. There is one class of equipment, however, which has presented a particularly difficult problem, a problem which is not yet completely solved. Optical instruments of all kinds—binoculars, telescopes, microscopes, cameras, range-finders and gunsights—rapidly become unserviceable in the tropics owing to growth of mould on lenses and prisms, and, since there is as yet no way of incorporating an antiseptic in optical glass, they cannot be protected in the same way as most other goods.

The problem is a very old one but, although some attempts were made to

solve it before the war, these efforts were on a small scale and somewhat spasmodic. During the war hundreds of thousands of instruments were in use, with the result that the damage was on such a scale as to make almost impossible demands on the available repair shops, and it became absolutely necessary to make every effort to stop the trouble.

In probably the majority of cases of serious damage, the mould occurring on glass surfaces originates on particles of dust, or on mites which find their way into the instruments. In the days when speed of production was all-important, many binocular bodies were imperfect, threads on focusing screws were often a poor fit and sealing compounds had not always the right physical characteristics. Under these conditions, dust, often of organic origin and carrying spores, readily entered, providing quite sufficient nutriment for appreciable growth of the moulds. However, even with perfect castings, satisfactory screw threads and the best lutings, it was found that mites often gained entry. These creatures are well known to all who keep collections of cultures, as they are very strongly attracted to moulds as a source of food, but, in optical instruments, the roles of predator and prey are often reversed. Mites often enter instruments when no mould is already present and not infrequently die there from lack of food. They carry spores on their hairy bodies, with the result that, after death, they provide much suitable food for the moulds.

Apart, however, from the occurrence of damage which can be accounted for in this way, there have been many cases of serious mould growth in optical instruments when, so far as could be ascertained, there was no foreign matter at all on the glass to serve as food for the fungus. We still do not know how mould can grow under these conditions. Spores will germinate in presence of water alone, but it is extremely doubtful whether the amount of mycelium found in typical cases could result from the material stored in a few spores. If it could not, it is difficult to see whence the mould derives the carbon and nitrogen necessary for growth.

During the war, of course, there was no opportunity for experimental work to solve what is a fascinating but nevertheless academic problem, the urgent requirement being to find some means of keeping glass surfaces free from contamination. Early attempts to keep down the relative humidity inside instruments, by paying careful attention to sealing and by filling with dry air or inert gas at the factory, met with little success. Any optical device with a focusing adjustment inevitably breathes to a certain extent, resulting in the gradual replacement of the dry air by the very humid air of the jungle. The next idea to be tried out was to maintain a fungicidal or fungistatic atmosphere, by means of small quantities of volatile antiseptic suitably placed within the instrument. To contain the antiseptic, very neat little metal capsules were used, made to screw in from the outside so as to permit of ready replacement. They were fitted with diaphragms of sintered glass, in order to retain solid particles whilst allowing free passage of the vapour. The only trouble was to find the perfect antiseptic. Up to the present two substances, metacresol acetate (known as 'cresatin') and thymol, have shown promising results, but cresatin, unless the dose is carefully controlled, tends to corrode metals and both substances soften

canada balsam, so that neither can be regarded as completely satisfactory. Another line of attack has been to use much the same type of metal capsules, but containing 'tell-tale' silica gel. Experiments in this country have confirmed the calculations of the physicists and shown that about half-a-gram of silica gel in each limb of a binocular will keep the internal atmosphere dry for two to three months, even when sealing of the joints is far from perfect. It is still not known, however, whether this method of protection will be adequate if instruments are subjected to fairly rough use under service conditions, and the final solution of the problem was by no means reached when the end of the war came. Research work is, of course, still proceeding, because troops are stationed in the Far East even in normal times, and, for some time to come, will be there in considerable strength.

All this work on tropical proofing needed, at the beginning, some knowledge of taxonomy of moulds and of physiology of fungi, but, when once organized, could be carried out by personnel of comparatively little experience. What will probably prove more important, in the long run, than the contribution which mycology was able to make to the war effort, is the effect of this work on the status of mycology. Interest in mould fungi has spread, not only amongst Service personnel, but amongst manufacturers of all kinds of products. Many manufacturers have, during the war, wished to carry out tests on their own products, tests of suitability to withstand tropical conditions. They have asked for instruction on the methods of carrying out the tests, on detection of mould growth on various materials and, not infrequently, have desired to be able to maintain their own cultures and make their own culture media. A number have asked where they can find literature to supply more information about fungi and have, in fact, become definitely fungus-conscious. As I have already said, a few of our industries were fully alive to the mould problem before the war, but now the interest has spread to manufacturers of such goods as wireless sets, insulated wires and cables, heavy electrical equipment, optical instruments, plastics, and paints and varnishes. The fact that some of these have encountered difficulties in their testing laboratories has made them realize that fungi are living organisms, showing all the vagaries associated with other forms of life, and this has stimulated their interest.

The other field of mycology in which great developments have occurred during the war is the study of the antibiotic activities of fungi. In 1940 appeared the first of a series of papers on penicillin, from the Oxford school under Prof. Florey, showing that this extraordinary substance is active against a number of bacteria *in vivo* as well as *in vitro*, that it is non-toxic and that it does not inactivate leucocytes. Concentrates were prepared and used with a gratifying measure of success in clinical trials, but the low and variable yields of the drug precluded any wider applications at the time. However, wide interest was aroused, both in this country and in America, large-scale research was initiated, and eventually methods of production were so much improved that sufficient penicillin was available just when it was most needed, in the first instance for battle casualties, later for treatment of a limited number of civilian cases.

The predominant part played by the U.S.A. in this development was not due entirely to large resources of money and man-power, but was undoubtedly owing in large measure to an early realization that the initiation of a large-scale mould fermentation is something more than a problem in chemical engineering. From the beginning mycologists were co-partners in the scheme, and to their efforts are due a number of the discoveries which have rendered possible the production of penicillin in adequate quantity and at an economic price. The main obstacles which had to be overcome were the low yield and the difficulty of carrying out the fermentation, on a sufficiently large scale, in shallow layers of liquid medium. The question of the poor yield was tackled by the obvious method of intensive cultural studies and considerable success was achieved thus. At the same time it was thought that it would be most extraordinary if only one strain of a not uncommon species had the ability to produce penicillin. Accordingly, an immense collection of moulds, from all kinds of substrata and from all parts of the world, was assembled and from this miscellaneous collection a large number of strains belonging to the *Penicillium chrysogenum-notatum* series were picked out for test. It was soon found that most strains showed some degree of antibacterial activity and a few of them were very much better than Fleming's original strain. Further, it was not long before a strain was found which would give good yields of the drug when grown in submerged culture. This made it possible to work with large volumes of culture fluid in deep tanks, instead of in numerous shallow vessels of small capacity.

On this side of the Atlantic it took longer to realize that *P. notatum* is a living organism. Several firms went into production without any idea that the services of a mycologist might, to say the least, be useful. It is little wonder that difficulties of all kinds occurred, or that very considerable amounts of penicillin were being produced in America at a time when production in England, its original home, was negligible. At the present time things are much better in this respect, there being quite a number of young chemists and botanists, who have had some training in mycology, now employed on penicillin production.

The importance of penicillin as a means of saving lives during the war can hardly be exaggerated. Its significance from the point of view of the effect of the war on mycology is less obvious but none the less real. It is not only a question of the employment of mycologists in production, and the demand is now greater than the supply, but the effect on the public imagination. Penicillin has become a popular topic of conversation and its production by a common green mould has at least made the average man aware of the existence of these lowly organisms.

Valuable as it is, penicillin is by no means the cure-all it is often imagined to be. Many pathogenic organisms are quite insensitive and it is not surprising, therefore, that intensive search has been made, in recent years, for other products of mould metabolism capable of curing diseases which penicillin does not touch. Several thousand species and strains have been tested but, so far, nothing so outstanding as penicillin has been found, most of the products being of lower antibacterial potency and, at the same time,

more toxic. However, some of them are potentially useful and, meanwhile, the search goes on.

It remains for me now to consider very briefly some ways in which the general interest in fungi, recently stimulated by the conditions of the war years, can be maintained and strengthened.

So far as workers in phytopathology and industrial mycology are concerned, the chief needs are for taxonomists, taxonomic literature and better opportunities for students wishing to take up mycology. I do not need to stress these points, because the report issued and widely circulated last year, on 'The Need for Encouraging the Study of Systematic Mycology in England and Wales', has dealt with the question of taxonomy, and a committee is at present studying the teaching of mycology and will make its report in the near future. As regards the attitude of the public to these subjects, I think more might be done, by means of popular articles and the radio, to keep interest alive. Probably, however, the best way to encourage this developing mycological sense is to do everything possible to stimulate the study of the larger fungi.

One of the chief requirements is for a hand-book in English, written in simple language and with a sufficiency of coloured illustrations. Many beginners are discouraged by the difficulty of trying to identify their finds from descriptions alone, descriptions often bristling with technical terms. Nothing gives more confidence and inclination to persevere, than the positive identification of a few species, and, for the tyro, there is no way so sure as the matching of a fungus with its picture. The writing of such a book depends, to a large extent, on individual inspiration, but the Society could do much to assist in publication when the material is available and might even encourage inspiration.

The other main requirement is for a great extension of field work, and here the Society can take the initiative. During recent years the numbers of forays have increased but the hunting has been, to a large extent haphazard, and I think the time has now come for some more definite work to be attempted. There are many things we should like to know concerning frequency of occurrence, range of variability, conditions which determine fructification, and the reasons for years of abundance and years of scarcity of various species. I venture to suggest that the best way, if not the only way, of initiating work on any problem of this kind is to enlist the aid of young people. The Foray Committee has endeavoured to interest various Natural History societies, but the most that can be expected from any such organization, in any one season, is a single outing devoted to the fungi. What is needed to begin with is the study of a number of comparatively small areas, week by week throughout the season. So far as I know, the only place where this has been attempted at all is at Haslemere, but there the demands of other departments of the Museum have limited the amount of time which could be devoted to fungi. From my own experience I have found that many schoolboys quickly develop a real enthusiasm for toadstools and I am convinced that a little preliminary propaganda in schools would lead to the formation of groups of young students ready to carry out regular surveys of their own neighbourhoods. At first they would, of course,

require some assistance from more experienced fungus-hunters, but that should not be an insuperable difficulty. Apart from the immediate benefits which would result, I think there is little doubt that a real interest in mycology in its wider sense would be aroused in many of the students and that we could hope for more mycologists, and in particular more systematists in embryo, from the next generation of university graduates.

If then we review in a general way the last six years, we see that, not only has mycology been of great service during the war, but appreciation of the importance of fungi has become widespread. It is the responsibility of the British Mycological Society to foster this appreciation and it has been presented with an opportunity such as it has never had before. Next year the Society celebrates its jubilee and I would urge that all who have its interest at heart should honour the occasion by putting forth that extra effort which will ensure mycology attaining its rightful place amongst the sciences.

NOTES ON SOME BRITISH FUNGI ASCRIBED TO *PHOMA* AND RELATED GENERA

By R. W. G. DENNIS, *Royal Botanic Gardens, Kew*

(With Plates I–III and 3 Text-figures)

Among minor diseases of the potato which have received little attention from mycologists are those associated with species of *Phoma*. Three of the latter have been credited with causing disease, namely, *P. solanicola* Prill. & Del., *P. tuberosa* Melhus, Rosenbaum & Schultz, and *P. foveata* Foister. *P. solanicola* was originally described as the cause of a stem rot of potatoes in France by Prillieux and Delacroix (1890), who did not prove its pathogenicity, while Köhler (1928), who rediscovered the species under similar circumstances in Germany, found it non-pathogenic to sound potato stems. The other two species were described in connexion with localized tuber rots and have both been shown by their authors to be feebly parasitic on healthy potato tuber tissue (Melhus, Rosenbaum & Schultz, 1916; Alcock & Foister, 1936). In addition, *P. solani* Cke & Harkness, *P. oleracea* Sacc., *P. nebulosa* (Pers.) Mout. and *P. eupyrena* Sacc. have all been recorded on potato stems. According to Wollenweber (1920) the last named was the cause of 'Pustelfaule' of potato tubers imported to Germany.

Owing to this multiplicity of names applied to pycnidial fungi with hyaline one-celled spores associated with the potato plant, plant pathologists have had much difficulty in identifying the causes of these minor *Phoma* rots. In association with a current investigation into the control of potato dry rot (*Fusarium caeruleum*), a re-examination of the *Phoma* rots was suggested to me by Dr C. E. Foister.

Preliminary isolations soon showed that three types of culture, presumably representing three distinct species of *Phoma*, could commonly be obtained from British potato tubers. As none were aggressive parasites it seemed likely that some or all of them would be found to be soil-inhabiting fungi not specialized as parasites of the potato or any other plant. If so, they might be found also on other hosts, living or dead, and then might have been described under different names on the various substrata. Consequently species of *Phoma* were collected during the spring and summer of 1944, mainly from herbaceous plants in the south-east of Scotland, and as many as possible were taken into culture. In order to economize time and media single-spore cultures were made only from the three types of growth directly associated with the potato tubers, from a *Phoma* on potato haulm and from one on dead stems of *Senecio* which apeared to be of particular interest. With other forms a single pycnidium was carefully picked out with a sterile needle, placed in a drop of sterile water until the spores oozed out and multispore isolations were made from this suspension. These have

the advantage that, at least in the first few transfers, they are more likely to show an 'average' type of mycelial growth than are single-spore cultures, which tend to segregate into extreme mycelial and pycnidial lines (see group II).

The forms studied are listed in Table 1 under strain numbers by which they will be referred to subsequently.

Differential criteria

In taxonomic work with the Sphaeropsidales the criteria mostly employed have necessarily been mainly morphological, such as the structure of the pycnidia, and the size, shape, septation, mode of production and colour in the mass of the spores. Unfortunately, owing to the small range in spore size shown by the majority of species of *Phoma*, these criteria are not sufficient for identification. Much stress has therefore been placed on the host plant or other substratum with the result that over twenty years ago Shear (1923) could point to the existence of over 1700 so-called species of *Phoma* and remark that 'To refer a species to *Phoma* at present is little more than a confession of ignorance of the organism in hand or its relationship'. Even after segregation of as many forms as possible in *Phomopsis*, *Macrophoma* and similar genera, Grove (1935) still lists 163 British 'species' of *Phoma*, all within a spore range of $2–20 \times 0{\cdot}5–7\,\mu$. In addition are twelve 'species' of *Aposphaeria* and 152 of *Phyllosticta* distinguished from *Phoma* solely by the substratum.

It has been demonstrated, especially by Wollenweber and Hochapfel (1936), that many species of *Phoma* have in fact a wide host range and a correspondingly extensive synonymy. Hence, although it is generally recognized that purely vegetative characters, especially the appearance of the mycelial mat in culture, tend to be less stable than the morphology of the fructification, such mycelial and cultural characters must be taken into consideration, to eke out the meagre range of differential criteria afforded by pycnidia and spores. In the following descriptions detailed accounts are given of the macroscopic appearance of Petri-dish cultures on malt agar (2 % malt extract, $2\frac{1}{2}$ % agar) grown in diffuse light at room temperature (*c.* 16° C.). The appearance and colour of the mat may vary somewhat with the thickness of the agar layer, which in the present work was maintained at approximately 2 mm. when freshly poured. Microscopic characters of the mycelium seem to be highly variable and hard to define, but the presence of peculiar and abundant chlamydospores is of value in distinguishing *P. eupyrena* Sacc. sensu Woll. and *P. alternariacearum*.

Additional criteria may probably be obtained from physiological characters, such as temperature range and optima for growth, ability to grow on a wide range of media or on the same medium at different *p*H concentrations and the like. Neither time nor facilities were available to me for such work, but even under the fluctuating temperature of the laboratory the strains could be separated into slow and quick-growing groups. It was possible to compare the isolates as regards their capacity for liquefying 10 % gelatine, as recommended by Grimes *et al.* (1932). At least two parallel

Table 1. *Sources of* Phoma *and other strains used in the investigation*

Strain no.	Original host	Organ attacked and date of collection		Current name	Locality	Collector
1	*Solanum tuberosum*	'Majestic' tuber	Feb. 1944	*Phoma foveata* Foister	Aberdeen	Miss E. Gray
2	,, ,,	,, ,,	Feb. 1944	? *P. tuberosa* M. R. & S.	Prestonkirk	Writer
3	,, ,,	Last year's stem	18. iii. 44	*P. solanicola* Prill. & Del.	Corstorphine	,,
4	*Senecio Jacobaea*	,, ,, ,,	23. iii. 44	? *P. herbarum*	,,	,,
5	,, ,,	,, ,, ,,	6. v. 44	? ,,	Greenlaw	,,
6	*Vinca minor*	Dead stem	3. v. 44	? ,,	Corstorphine	,,
7	*Sonchus oleraceus*	Last year's stem	30. v. 44	*Diplodina Sonchi* Henn.	,,	,,
8	*Linum usitatissimum*	Stem rot	30. vi. 44	*Phoma* type } *A. linicola* Naumoff	Turriff	Miss E. Gray
9	,, ,,	,, ,,	30. vi. 44	*Ascochyta* type } & Vassilievski	,,	,,
10	*Lonicera Periclymenum*	Living leaf	5. vii. 44	*Phyllosticta Lonicerae* Westd.	Cupar, Fife	Writer
11	*Lycopersicum esculentum*	Stem	—	*Diplodina Lycopersici*	Received from Cheshunt Exp. St.	,,
12	*Hedera helix*	Living leaf	6. vi. 44	*Phyllosticta hedericola* Dur. & Mont.	Bridge of Allan	,,
13	*Fraxinus excelsior*	Fallen fruit	8. v. 44	? *Phoma Aceris-negundinis* Arc.	Greenlaw	,,
14	,, ,,	,, ,,	18. iv. 44	Uncertain	Corstorphine	,,
15	*Centaurea Scabiosa*	Last year's stem	6. v. 44	? *Phoma herbarum*	Greenlaw	,,
16	*Ribes Grossularia*	Living leaf	11. ix. 44	*Phyllosticta Grossulariae* Sacc.	Achnashellach	Miss E. Gray
17	*Solanum tuberosum*	'Majestic' tuber	Feb. 1944	*Phoma eupyrena* Sacc.	Prestonkirk	Writer
18	,, ,,	Tuber	—	,, ,, ,,	England	A. R. Wilson
19	*Heracleum Sphondylium*	Last year's stem	21. iii. 44	*P. complanata* Desm.	Corstorphine	Writer
20	*Urtica dioica*	Base of last year's stem	18. iii. 44	*P. acuta* Fckl.	,,	,,
21	*Sisymbrium officinale*	,, ,, ,, ,, ,,	23. iii. 44	Uncertain	,,	,,
22	Unidentified Umbellifer	,, ,, ,, ,, ,,	12. iv. 44	Uncertain	Pass of Leny	,,
23	*Lapsana communis*	,, ,, ,, ,, ,,	14. iv. 44	? *Phoma Lampsanae* Karst	Ardeonaig, L. Tay	,,
24	*Anthriscus sylvestris*	,, ,, ,, ,, ,,	12. iv. 44	Possibly *P. sanguinolenta* Grove	Pass of Leny	,,
25	*Urtica dioica*	Last year's stem	20. iii. 44	? *P. Urticae* Sch. & Sacc.	Corstorphine	,,
26	*Angelica sylvestris*	,, ,, ,,	13. iv. 44	? *P. oleracea* Sacc.	Balquhidder	,,
27	Cream	—	—	*P. hibernica* Grimes *et al.*	Cork, Eire, June 1944	Prof. M. Grimes
28	*Urtica dioica*	Last year's stem	12. iv. 44	*P. nebulosa* (Pers.) Mont.	Callander	Writer
29	*Scrophularia nodosa*	,, ,, ,,	12. iv. 44	*P. oleracea* Sacc.	L. Lubnaig	,,
30	*Solidago Virgaurea*	,, ,, ,,	14. iv. 44	? *P. herbarum* f. *Solidaginis*	Glen Lednock	,,
31	*Galium aparine*	,, ,, ,,	6. v. 44	*Diplodina Gallii* (Niessl) Sacc.	Greenlaw	,,
32	*Ribes Grossularia*	Bark of living twig	7. v. 44	*Diplodina Grossulariae* Sacc. & Bri. sensu Grove	Greenlaw	,,
33	Swedish turnip	'Root'	Feb. 1944	*Phoma lingam* (Fr.) Desm.	Corstorphine	,,
34	*Lycopersicum esculentum*	Fruit	—	*P. alternariacearum* Brooks & Searle	Received from Prof. Brooks	

tubes were inoculated with each strain and maintained at room temperature. The rate of liquefaction by different isolations of the same fungus was sufficiently constant for this character to be regarded with some confidence as a differential criterion.

Degree of pathogenicity to selected host plants may also afford a useful clue to the relationship of any particular isolate. It has to be remembered, however, that it is not unusual to find non-parasitic or weakly parasitic strains of common fungus parasites and also that pathogenicity may decline with prolonged cultivation on artificial media. Thus Foister's original isolate of *P. foveata*, maintained in the National Collection of type cultures, was found to be no longer pathogenic to potato tubers. Similarly the culture of *P. alternariacearum* received from Prof. Brooks would not attack tomato fruit.

By the use of the above criteria the thirty-four strains have been classified in seventeen groups. Whether or not these represent 'good' species will be a matter of opinion. Thus in group II strains 2, 3, 4 and 5 appear to be identical, strain 6 seems to be a less active parasite, strain 7 had a higher proportion of septate spores in the original collection, strain 9 differs slightly in appearance of the mycelial mat, while strains 8 and 9, though of the same general type, differ from the others in pathogenicity to flax. It is obviously undesirable to attempt to allot valid names to any of the groups until all or nearly all the described species of *Phoma* have been studied in culture. Any name allotted at present will be liable to be invalidated by the discovery that an earlier described species on a different host fell into the same group of strains. The nomenclature adopted is therefore, as far as practicable, that of Grove (1935), which seems likely to be in use in Britain for many years.

Inoculation experiments

(*a*) *On potato tubers.* All inoculations were made on tubers of the variety Doon Star, which is known to be particularly susceptible to the 'gangrene' type of *Phoma* rot. They were made by inserting a minute piece of an agar culture under the small flap of skin left by a cut 2–3 mm. long on the surface of the washed tuber. Inoculated tubers were kept under bell jars on the surface of moist peat or sphagnum. During spring and early summer of 1944, tubers of a 1943 crop were inoculated with strains 1–6, 11, 13–15, 17–34, while on 18 September 1944 freshly lifted tubers were inoculated with strains 7–10, 12 and 16. This point is of importance, since it is known that the susceptibility of potato tubers to Dry Rot and Gangrene appears to increase during storage over winter, which must be taken into account in comparing the lesions produced on the two seasons' crops.

There were three types of reaction on potato tubers. In the majority of cases no invasion of the tissues took place, though the flap of skin usually shrivelled. In the second type, exemplified by strains nos. 1, 2, 3, 4, 5, 6, 7 and feebly by 8, 9, 10 and 13 a small, more or less circular, hard, dark rot developed. This usually became sealed off in a few weeks and extended no further in diameter, though the depth might be successively extended to

about 1 cm. The dried-up dead tissue could usually be prised out after about one month, leaving a clean healed cavity behind. This is the button type of rot, which, especially with strain 1, occasionally progressed more deeply, with formation of cavities in the dead tissue, as in typical gangrene. Pycnidia developed on the lesions formed by strains 1, 2, 3, 4, 5 and 7. The third type of reaction, shown only by *Diplodina Lycopersici*, was a rather rapid but shallow subepidermal rot which rapidly spread over the surface of the tuber. Mature pycnidia were produced on the diseased tissue and yielded spores from which the fungus was easily reisolated.

(*b*) *On swede roots.* Mature purple-topped swede roots were obtained from a clamp in the spring of 1944 and inoculated in the same way as the potato tubers. The same three types of reaction were shown, namely: no invasion; localized circular lesions by strains 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 13; and extensive rot by *Phoma lingam*, strain 33, only. Pycnidia were produced on swede roots only by the latter. A few strains had to be tested on roots fresh from the field in September 1944 and, as with potato tubers, the lesions produced were smaller than those on the overwintered roots. Thus strain 2, which formed lesions 6–12 mm. across on roots inoculated 28 March 1944, produced them only 4 mm. across on roots inoculated 7 September 1944. In neither instance did the lesions increase in size after the first week. Even lesions only 4 mm. across, however, are quite distinct from the negative reaction given by most strains.

(*c*) *On tomato stems.* Young tomato plants about 12–18 in. high were obtained in individual pots from a local nursery and inoculated in the stem about 2 in. above soil level in the same way as potatoes and swedes. At the point of inoculation the stem was then wrapped round with a strip of oiled paper which was removed after three or four days. Here again most strains induced no lesions. Others formed a small rather dry canker. If this developed far enough to girdle the stem, the plant wilted and died (Pl. II, fig. 11). If not, the canker dried up and the plant grew normally, apart from the production of adventitious root rudiments above the lesion. Girdling and death took place with some inoculations of strains 1, 2, 3, 4, 5, 7, 8 and 11, cankers without girdling with strains 6 and 13. No sharp distinction can be drawn, however, between these two groups, as of a number of inoculations made at the same time from the same culture one might result in girdling and the others not, even in strain 11. Pycnidia developed on the lesions caused by strains 1, 2, 3, 4, 5, 7, 11 and 13. Other plants of similar size were sprayed with spore suspensions of strains 1, 2, 3, 4, 6 and 11. The results of this experiment were less clear cut and are described under groups I, II and III.

(*d*) *On tomato fruit.* Picked fruit stored in a single layer on the floor of a large closed tin were inoculated by cuts in the usual way when fully grown and just turning yellow. A clear-cut distinction can be drawn between strains which rotted the fruit rapidly and those which were completely non-parasitic. Positive results were obtained with strains 1, 2, 3, 4, 6, 7, 8, 9, 10, 11 and 13. Strain 5 was not tested (Pl. III, fig. 3).

(*e*) *On apple fruit.* This host was chosen to facilitate comparison with the species described by Wollenweber and Hochapfel (1936). Unfor-

tunately the only variety of which fruit were available to the writer in sufficient quantity free from other diseases, especially scab, was a little-known one, called locally Ben's Red. This may have been somewhat resistant to *Phoma* rots (as it appears to be to scab), as in many cases the rot did not proceed beyond a small lesion 3 or 4 mm. in diameter round the point of inoculation. Other inoculations, often with the same strains as those which remained thus circumscribed, produced a rather slow brown rot, over the central portion of which developed a black crust of hyphae but

Table 2. *Results of inoculation experiments with* Phoma *strains*

Strain	Potato tuber	Swede root	Tomato stem	Tomato fruit	Apple fruit
1	+	+	+	+	+
2	+	+	+	+	+
3	+	+	+	+	+
4	+	+	+	+	?
5	+	N.T.	+	+	N.T.
6	+	+	+	+	?
7	+	+	+	+	+
8	+	+	+	+	?
9	+	+	N.T.	+	?
10	+	+	? +	+	+
11	++	+	+	+	?
12	−	−	−	−	−
13	+	+	+	+	?
14	−	−	−	−	−
15	−	−	−	−	−
16	−	N.T.	N.T.	−	−
17	−	−	−	−	−
18	−	−	−	−	−
19	−	−	−	−	−
20	−	−	−	−	−
21	−	−	−	−	−
22	−	−	−	−	−
23	−	−	−	−	−
24	−	−	−	−	−
25	−	−	−	−	−
26	−	−	−	−	−
27	−	−	−	−	−
28	−	−	−	−	−
29	−	−	−	−	−
30	−	−	−	−	−
31	−	−	−	−	?
32	−	−	−	−	−
33	−	++	−	−	−
34	−	−	−	−	−

no mature pycnidia. In the table above the former type of reaction is indicated by a ?, the latter, even if only from a few inoculations, by a +. Foister (unpublished observations) has previously shown *P. foveata* to be able to rot apple fruit.

The results of all these inoculation experiments are collected in Table 2. The three types of reaction on tubers and swedes are indicated by −, + and + +, those on tomato stems and fruit by − and +. N.T. signifies not tested. Unless otherwise stated, potato tuber observations are based on ten inoculations or more (see Table 4), those on the swede on five inoculations on the same root, those with tomato stems on two plants, and with

tomato and apple fruit on two inoculations on opposite sides of each of two fruit.

Descriptions of the individual strains

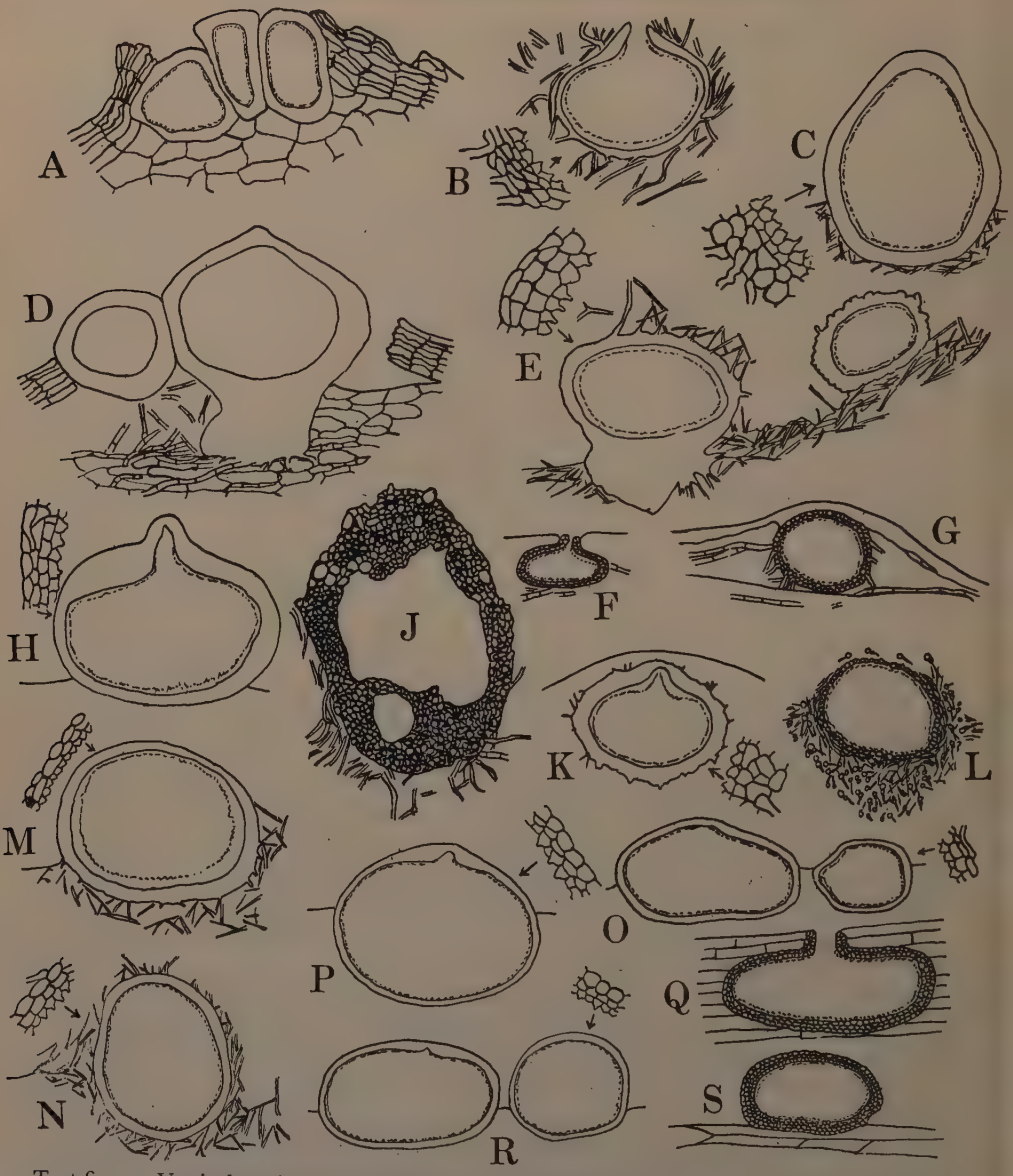
Group I. Phoma foveata Foister. For the first three days of growth there is a short, mealy, white aerial mycelium without zoning. By the fourth day a light yellow-brown tint appears at the centre of the culture and by the fifth day dark, submerged hyphae are present in irregular brown patches forming a zone of inner diameter 5–6 mm. As the culture grows the colour becomes intensified until the entire mat appears teak colour, with indistinct zones of greyish white aerial hyphae (Pl. I, fig. 1). Over the central area the colour of the aerial mycelium itself is yellow-brown, but the colour of the whole culture is dominated by that of the dark submerged hyphae showing through the sparse mat. When viewed from below the distinct, though irregular and discontinuous concentric belts of dark olive-brown hyphae are characteristic of all isolations referred to this species (Pl. I, fig. 2). Mature pycnidia are not found on agar plates, but scattered sclerotial bodies interpreted as immature pycnidia occur. Mature pycnidia occasionally develop on old malt-agar slants (Text-fig. 1 B). Brush streak cultures with a spore suspension on agar plates yield the same type of growth. An irregular, broken line of immature pycnidia develops along the streak, but there is no distinct clear belt on each side of this as in group II. The remainder of the culture is occupied by alternating zones of light and dark submerged hyphae like those on plates inoculated at the centre in the usual way.

On sterilized potato plugs the fungus forms a dense, short, pinkish brown mycelial mat in which are embedded innumerable clusters of black pycnidia (Text-fig. 1 A). At the upper dry end of the plug the growth is looser, more erect and grey-brown with white hyphal tips. Where the edge of the plug impinges on the glass of the tube a dark brown, almost chocolate-coloured band is visible with a fringe of similar coloured hyphae growing over the glass surface.

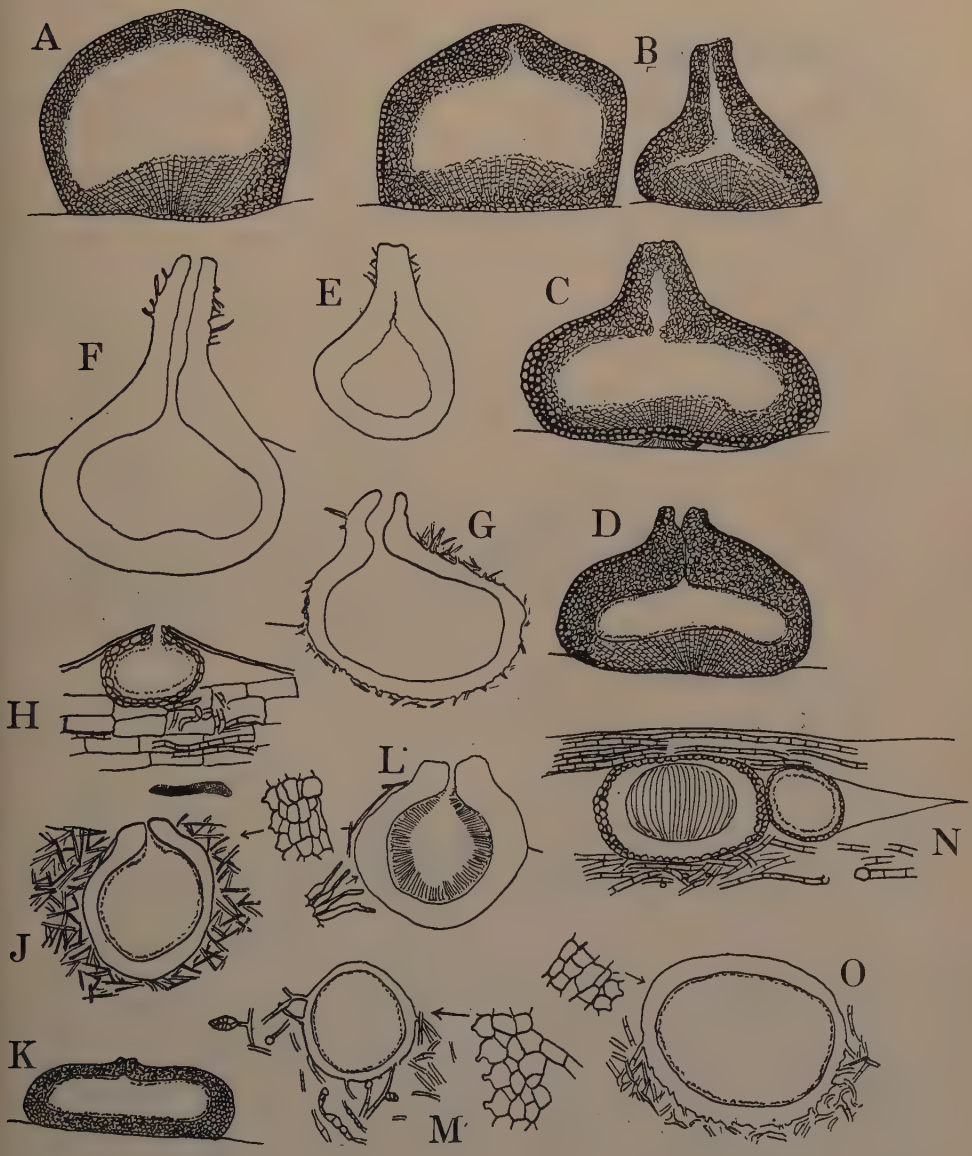
Strain 1 liquefied gelatine to the extent of 12·5 mm. in fifteen days and 21 mm. in thirty days. Foister's original isolation of *P. foveata* received from the National Collection of Type Cultures differed from the above in having little or no aerial growth and in producing pycnidia very freely on malt agar slants.

Strain 1 was parasitic to Doon Star tubers, on which it caused button type or small gangrene lesions of mean diameter 17·4 mm. On these pycnidia were produced in abundance, singly or fused into irregular groups arranged in more or less distinct concentric circles. They were black, immersed or almost superficial and exuded a pink exudate which dried carrot colour. According to the diagnosis, *P. foveata* has spores 'yellow-cream' in the mass (Foister, 1940). The colour of the exudate in the original isolation now corresponds, however, with that of strain 1 which is accepted as *P. foveata* by Foister.

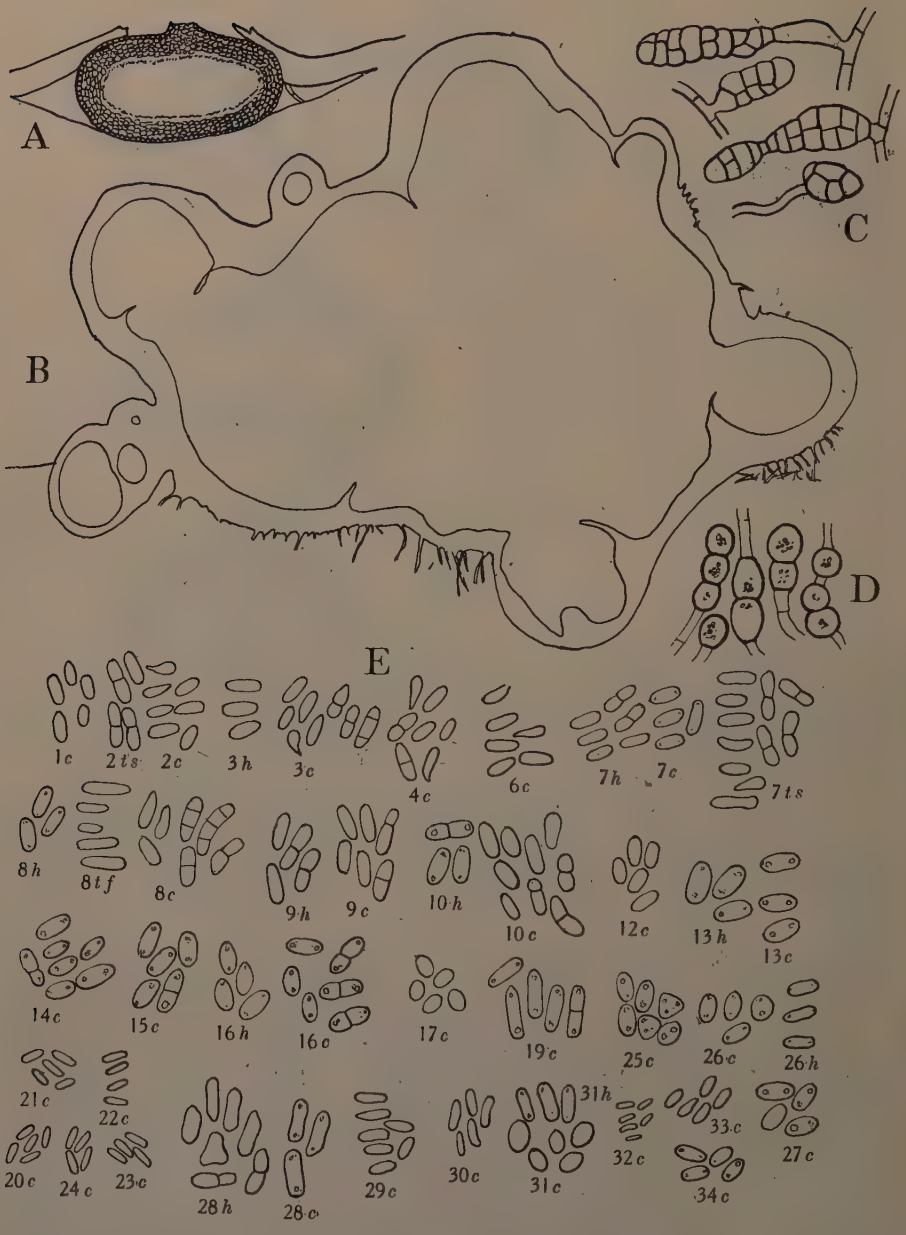
The spores are colourless, cylindrical with rounded ends and non-



Text-fig. 1. Vertical sections of pycnidia, from camera lucida tracings to the same scale, all ×*c.* 70. Details of pycnidial wall, ×*c.* 500. Unless otherwise specified, all cultures referred to are on malt agar. A. Strain 1 on potato tuber. B. Strain 1 in tube culture 111 days old. C. Strain 3 in 6 weeks old culture. D. Strain 2 on potato tuber. E. Strain 4 in 65 days old culture. F. Strain 4 on *Senecio* stem. G. Strain 3 on old potato stem. H. Strain 12 in 5 weeks old culture. J. Strain 11, immature pycnidium in 55 days old culture. K. Strain 19 in 55 days old culture. L. Strain 18 in culture, pycnidium embedded in mycelium full of chlamydospores. M. Strain 13 in 40 days old culture. N. Strain 14 in 28 days old culture. O. Strain 27 in 37 days old culture. P. Strain 25 in culture 55 days old. Q. Strain 25 on *Urtica dioica* stem. R. Strain 26 in culture 26 days old. S. Strain 26 on *Angelica* stem.



Text-fig. 2. Explanation as Text-fig. 1. A. Strain 21 on *Sisymbrium* stem. B. Two pycnidia of strain 24 on *Anthriscus* stem. C. Strain 22 on the host. D. Strain 20 on *Urtica dioica* stem. E. Strain 22 in culture 53 days old. F. Strain 24 in culture 57 days old. G. Strain 21 in culture 55 days old. H. Strain 30 on *Solidago* stem. J. Strain 30 pycnidium embedded in mycelium on potato plug culture 28 days old. K. Strain 19 on *Heracleum* stem. L. Strain 32 in culture. M. Strain 34 in culture 11 weeks old. N. Strain 28 on *Urtica* stem, pycnidium in contact with perithecium of *Didymella* sp. O. Strain 28 in 28 days old culture on potato plug.



Text-fig. 3. A. Pycnidium of strain 29 on *Scrophularia* stem, × 70. B. Multilocular fructification of strain 29 in culture 28 days old, × 70. C. Chlamydospores of strain 34, × 500. D. Chlamydospores of strain 17, × 500. E. Pycnospores (× 500) of the strains indicated by number. *h*=from the host; *c*=from artificial culture; *ts*=from tomato stem; *tf*=from tomato fruit.

septate (Text-fig. 3 E 1). The dimensions are somewhat larger than those cited by Foister, viz.:

From pycnidium on 3 months old agar slant	$7{\cdot}5 \times 2{\cdot}9$ ($5{\cdot}6$–$9{\cdot}3 \times 2{\cdot}2$–$3{\cdot}6$ and up to $4{\cdot}8$) μ
On Doon Star tuber	$6{\cdot}6 \times 2{\cdot}9$ ($4{\cdot}8$–$8{\cdot}2 \times 2{\cdot}8$–$3{\cdot}4$) μ
On tomato stem	$7{\cdot}5 \times 3{\cdot}3$ ($5{\cdot}0$–$11{\cdot}5 \times 2{\cdot}8$–$3{\cdot}9$) μ
Foister's diagnosis (from tuber)	$5{\cdot}7 \times 1{\cdot}7$ ($3{\cdot}2$–$7{\cdot}7 \times 1{\cdot}1$–$2{\cdot}1$) μ

The mycelium in culture varies from hyaline to light brown, composed of elongated cells typically crowded with oil globules. In old submerged hyphae individual cells commonly round off to form long-elliptical chlamydospores which may germinate to give rise to one or more narrower hyphae within the original hyphal wall.

When inoculated to tomato stems strain 1 caused girdling and falling over of the plant in nine days, followed by copious production of pycnidia on the lesion. Spore suspension sprayed over two tomato stems on 23 May caused an occasional leaf spot on the lower fading leaves, but no apparent stem lesion. Pycnidia developed on these leaf spots when the leaflets were picked and kept five days in a damp Petri dish. Strain 1 was successfully recovered from these pycnospores. Both plants, however, wilted and died simultaneously about two months later while control plants were still vigorous and strain 1 was reisolated from the dead stem tissue. Green tomatoes were rotted freely, lesions 12 mm. in diameter being formed in seven days. Inoculation to apple yielded a somewhat slow brown rot on which immature pycnidia began to appear after four weeks. Foister's original isolate of *P. foveata* was no longer pathogenic to potato, tomato fruit or to apples, and formed only small cankers on tomato stems.

Isolates identical in appearance with strain 1 were obtained from Majestic tubers from Prestonkirk, Ninetyfold and Doon Star from Dumfries, Craigs Defiance and a seedling from Edinburgh, and were also received from Drs Boyd and Wilson at the Midland Agricultural College.

Group II. In this group are included strains 2–10 inclusive, isolated from potato, ragwort, periwinkle, sowthistle, flax and honeysuckle. These all behaved similarly in culture and gave similar though not identical reactions when inoculated to the differential hosts. All are liable to produce a number of 1-septate spores, but the percentage of these fluctuates considerably between different isolates and even with the same isolate on different substrates and in pycnidia of different ages. Thus no septate spores were found in the exudate in a single-spore culture of strain 4 five weeks old. When it was eight weeks old about 1 % of the exuded spores were septate. Hence some of the strains may be classified as *Phoma* or *Phyllosticta*, others as *Diplodina* or *Ascochyta*. All may not ultimately be considered to belong to a single species, but they appear to be closely related and to form a natural group.

Growth in culture begins as a rather loose white aerial mat, which straggles up to a height of 3 mm., and develops rather characteristic tangential white crests round the margin on the second day. By the fifth day the central mat becomes closer, shorter and takes on a grey tinge, sur-

rounded by a dense white belt with an irregular extending margin which is already distinctly crenate. By the sixth day olive-grey tangential streaks appear among the submerged hyphae apparently corresponding in position to the white crests of the second day's growth. The culture darkens rapidly and by the eighth day the central area appears solid black below, covered by a straggling grey aerial mat. By the twelfth day almost the whole surface of the culture is covered with a dense olive-grey mat with looser whitish tips. Between this and the narrow whitish marginal zone is usually a belt where the dark submerged hyphae are visible from above, owing to the sparseness of the aerial mat. By this time the margin is usually very irregular, owing to growth taking place irregularly over short arcs, corresponding to which are forked and branched tongues of blackish submerged mycelium. Vague zoning may be apparent in the submerged growth and black hyphal knots and immature pycnidia appear (Pl. I, figs. 4–6).

On potato plugs there is a dense even coat of dark grey mycelium, looser and paler at the upper end and forming an almost black band where the plug is in contact with the glass. Pycnidia were abundantly produced by strain 2 on this substrate, but on agar plates and slants pycnidial production was somewhat irregular. The original mycelial isolation of strain 2 produced very few pycnidia on malt agar, though hyphal knots were frequent especially along the glass of tube cultures. A line of ripe pycnidia developed, however, all round the margin of a slant which had been removed from its tube and left for eight days in a dry Petri dish. Single spore cultures made from the exudate of this strain on a potato plug segregated into two groups, one showing predominantly mycelial growth with only occasional pycnidia, the other less copious aerial mycelium and abundant pycnidia. This is evidently an instance of the 'Dual Phenomenon' described by Hansen (1938) in *Phoma terrestris* and other imperfect fungi. The difference between the two groups remained constant over a series of transfers, but it is somewhat surprising that of seven single-spore isolations made from a single pycnidium of each of strains 3 and 4 those of the former were all of the mycelial type and those of the latter all pycnidial. The remaining strains of which multispore isolations only were made produced pycnidia somewhat sparsely in culture. In strain 6 pycnidia were produced round the edge of a hole in the culture from which inoculum had been taken.

Brush streak cultures of strain 2 with a spore suspension from potato plugs gave copious pycnidial formation down the line of the streak, which was marked by an irregular belt of dark submerged hyphae bordered on each side by a narrow, barely continuous, clear zone. Beyond this the plate was covered with the normal grey mycelial growth covering blackish submerged hyphae and almost devoid of pycnidia. The clear bands were about 1 mm. wide, about 15–16 mm. apart, and scarcely discernible from above. Otherwise the appearance resembled that described by Köhler (1928) for *P. solanicola*. Strains 2, 3 and 4 grown together on the same plate appeared identical (Pl. I, fig. 4). Strain 10 gave a rather lighter grey aerial mat and less dark submerged mycelium than the others and may possibly be distinct (Pl. III, fig. 6).

Growth rates of the strains of group II varied considerably as did those

of the same isolate at different transfers or even on plates made simultaneously from the same inoculum. Most strains grew fairly quickly for the first three or four days, after which the growth rate fell off with initiation of the crenate margin and localized extension of individual arcs. Growth sometimes ceased altogether before the margin of the plate was reached.

Spores of all strains are cylindrical with rounder ends or slightly narrowed to one end, but somewhat irregular spores are not infrequent. There is only very slight constriction at the septum when it is present. In all cases the spore exudate is pink. The spore dimensions of individual strains grown on different substrates are set out in Table 3, which also includes the spore dimensions of a fungus isolated from basal lesions of flowering *Brassica sinapis* plants from a flax field at Errol, Perthshire. It appeared to belong to group II, but was not further studied. Occasional 2-septate spores measuring $11–14{\cdot}6 \times 3{\cdot}9–4{\cdot}8\mu$ were seen in strains 5, 8 and 9 and the Charlock fungus, and a solitary 3-septate spore measuring $14{\cdot}4 \times 3{\cdot}9\mu$ in strain 8.

The behaviour of the group II strains when inoculated to Doon Star tubers has been summarized in Table 2, but is set out in more detail in Table 4, along with the data on rate of liquefaction of gelatine.

All strains produced the same type of localized lesion on swede roots, seldom exceeding 1 cm. in diameter. All rapidly rotted green tomato fruit and all produced cankers on tomato stems, but whereas at least some inoculations with strains 2, 3, 4, 5, 7 and 8 led to lesions which girdled the stem and killed the plants, none of strains 6 and 10 did so. Strain 9 was not tested on tomato stems. Pycnidia were produced on the cankers of strains 2, 3, 4, 5 and 7.

With a view to investigating the relationship of the group II strains to group III (*Diplodina Lycopersici*) a number of young tomato plants were sprayed with spore suspensions of strains 2, 3, 4, 6 and 11. The results may be summarized as follows:

Strain 11: Grey foliar lesions 5 mm. across with concentric zones and ripe pycnidia in five days. Stem lesions apparent and lower leaves wilted in 17 days, plants eventually killed.

Strain 2: Grey lesions on leaves and fading cotyledons with ripe pycnidia in 9 days. Three small stem lesions up to 3×1 mm. after eleven days. No further development.

Strain 3: Grey lesions on leaves and cotyledons with ripe pycnidia in 9 days. No stem lesions, but a solitary lesion near base of a petiole in eleven days.

Strain 4: Foliar lesions in six days with pycnidia in nine days from which the strain was recovered in culture. Eight stem lesions up to 10×2 mm. after eleven days, but these developed no further. Four pycnidia were noted on them after twenty-three days.

Strain 6: Small grey lesions up to 2 mm. across on the second and third leaves only, no pycnidia and no stem lesions.

It will be seen that though strains of this group are capable of attacking uninjured leaves of young and vigorous tomato plants they are all much less aggressive than *Diplodina Lycopersici*.

In this connexion it is worth recording that in the case of a tomato plant

Table 3. *Spore characters of the strains in Group II* (Text-fig. 3 E)

Strain	Substrate	Size of non-septate spores	1-septate spores	Approx. % septate
2	Original isolate } Agar	6·3 × 2·6 (5–9·8 × 2·2–3·1) μ	—	0
	Pycnidial type } Agar	7·0 × 3·5 (4·8–8·7 × 2·8–4·5) μ	—	0
	Mycelial type } Agar	7·0 × 3·6 (5·0–10·1 × 3·1–5·0) μ	—	0
	Tomato stem	8·0 × 3·6 (7–10 × 3–4·2) μ	10·6 × 3·5 (9–12 × 3–4) μ	30
3	Agar 8 weeks old	7·9 × 3·2 (6·4–10·1 × 2·8–3·9) μ	9·6 × 3·6 (8·4–11·0 × 3·3–4·2) μ	8
	Potato haulm	8·0 × 3·4 (6·7–9·0 × 2·8–4·0) μ	—	0
	Tomato stem	7·5 × 3·4 (5·0–10·1 × 2·8–3·9) μ	10·6 × 3·8 (10·1–11·3 × 3·3–4·5) μ	3
4	Agar 8 weeks old	7·2 × 3·5 (5·0–9·6 × 3·1–4·2) μ	9·6 × 3·5 (8·5–10·7 × 3·1–4·2) μ	1
	Tomato stem	8·4 × 3·6 (5·9–10·7 × 2·8–4·2) μ	10·3 × 4·0 (9–12·5 × 3·3–4·8) μ	7
5	Agar 9 weeks old	6·6 × 3·5 (4·2–8·7 × 2·5–3·6) μ	8·6 × 3·7 (7·6–10·4 × 3·1–3·9) μ	less than 1 : 1000
6	Agar 3 weeks old	6·3 × 3·1 (4·5–8·2 × 2·8–3·7) μ	—	0
7	Agar 7 weeks old	6·6 × 3·2 (4·7–9·0 × 2·5–3·9) μ	—	0
	Sonchus stem	7·4 × 3·2 (5·6–9·3 × 2·8–3·9) μ	9·7 × 3·7 (7·6–11·8 × 3·3–3·9) μ	7
	Tomato stem	8·5 × 3·2 (6·7–10·2 × 2·8–3·7) μ	10·3 × 3·5 (9·3–12·4 × 3·3–3·7) μ	2
8	Agar 4 weeks old	7·5 × 3·3 (4·2–10·1 × 2·8–3·7) μ	10·0 × 3·8 (8·5–11·8 × 3·3–4·2) μ	1
	Flax stem	6·5 × 3·1 (5·6–7·6 × 2·8–3·6) μ	—	0
	Tomato fruit (crushed pycnidia)	7·9 × 3·4 (5·9–10·4 × 2·2–4·2) μ	—	0
9	Agar 9 weeks old	7·7 × 3·1 (5·6–11·0 × 2·8–3·7) μ	10·8 × 3·4 (9·0–13·8 × 2·8–3·9) μ	3
	Flax stem	Not measured	10·0 × 3·7 (8·7–11·0 × 3·1–4·2) μ	11
10	Agar 8 weeks old	6·8 × 3·5 (5·0–10·1 × 3·1–4·2) μ	9·6 × 4·2 (7·9–12·7 × 3·3–4·5) μ	less than 1
	Honeysuckle leaf	7·5 × 3·7 (6·4–8·5 × 3·1–4·2) μ	(9·5–10·4 × 3·9–4·2) μ	?
	Tomato fruit (crushed pycnidium)	6·4 × 3·0 (5·6–8·5 × 2·5–3·6) μ	—	0
Charlock fungus	Agar 6 weeks	7·2 × 3·0 (5·0–9·0 × 2·5–3·7) μ	9·4 × 3·4 (8·4–11·3 × 3·1–3·7) μ	?

sprayed with *D. Lycopersici* spore suspension on 23 May and killed by a girdling lesion about 1½ in. above soil level, a secondary shoot sprouted from the axil of the second leaf, a short distance below the lesion. By 20 June this shoot was also killed and the entire stem down to soil level was eventually rotted. In a similar plant, girdled and killed after inoculation with the Senecio strain 5 on 16 April three such secondary shoots developed and remained healthy and vigorous until the plant was discarded at the end of July. Lesions induced by strains of group II evidently become localized either before or after girdling has taken place, whereas the tomato is unable to localize infection by *D. Lycopersici*.

Lesions were produced on apple fruit by all strains of this group, but whereas those of strains 4, 6, 8 and 9 remained localized and did not exceed 4, 5, 5 and 5 mm. in diameter respectively, those of strains 2, 3, 7 and 10

Table 4

Strain no.	Depth of gelatine liquefied in 15 days mm.	Depth of gelatine liquefied in 30 days mm.	Date of inoculation	Doon Star tuber inoculations: No. of successful inoculations	Total no. made	Mean diameter of lesions mm.	Range in diameter of lesions mm.
2	10½	21	10. 2, 27. 3 and 18. 4. 44	30	30*	9·6	6–13
3	9	19	27. 3 and 18. 4. 44	14	14*	10·7	8–15
4	8½	17	29. 3. 44	24	24*	10·0	7–11
5	11	23	16. 5. 44	7	10*	7·6	4–12
6	10½	21	16. 5. 44	6	10	4·0	2–9
7	14	23	10. 6. 44	9	10*	6·3	3–10
8	13	26	18. 7 and 18. 9. 44	?	22	3·0	2–5
9	—	—	18. 9. 44	?	12	3·0	2–4
10	12	24	18. 7 and 18. 9. 44	?	22	3·0	2–4

It will be observed that the strains appear to form a series of decreasing pathogenicity to potato tubers, until in the case of strains 8–10 it is not always possible to decide whether a small lesion has been formed or not. It must be remembered, however, that these were tested only on freshly dug tubers or on shrivelled specimens kept in store till mid-July. No difference in pathogenicity was shown by the mycelial and pycnidial lines of strain 2, which gave lesions of mean diameter 9·3 and 10·1 mm. respectively. Mature pycnidia were formed on the lesions produced by the strains indicated by an asterisk (Text-fig. 1 D).

developed further and gave rise to a rather slow brown rot of the whole fruit.

From an examination of the specimens in Grove's herbarium, preserved at Kew, it seems likely that strain 3 corresponds to his interpretation of *Phoma solanicola* Prill. & Del. According to the original diagnosis this has spores $7{\cdot}5 \times 3\,\mu$. Köhler, who studied what he believed to be the same species, obtained spores from agar cultures with an average size of $5{\cdot}99 \times 2{\cdot}80\,\mu$. The description of his cultures on malt agar agrees reasonably well with the appearance of group II though neither he nor Prillieux and Delacroix recorded the presence of septate spores. Köhler's measurements were mostly made on unextruded spores; for extruded spores, comparable to those measured by the writer, he obtained a higher value, viz. $8{\cdot}64 \times 3{\cdot}54\,\mu$. Grove's collection from Wishaw has non-septate spores $6{\cdot}0 \times 2{\cdot}5$ $(4–7 \times 2–3)\,\mu$.

Strain 2 may well represent *Phoma tuberosa* of Melhus, Rosenbaum and Schultz (1916), described as having spores 3·7–6·1 × 1·8–3·7 μ and as causing lesions very similar to those made by the fungi of group II. The original description of this species is quite inadequate, but the statements that the mycelial growth is 'whitish at first and at the end of a week begins to darken to the characteristic grey of *Phoma* spp.; the pycnidial development is very scarce. On potato cylinders the growth is fluffy and white, turning to grey within eight or nine days, the entire culture turning dark after the development of numerous pycnidia', is applicable to strain 2. *P. tuberosa* was originally described in 1914, but has subsequently been recorded from Maine (Anon. 1933), the Netherlands (van Poeteren, 1928), and, with some doubt, from England (Pethybridge, 1926). Unfortunately neither authentic material nor cultures of the American form could be obtained for comparison.

No fungus corresponding to strains 4 and 5 has been found in Grove's herbarium and it is doubtful what name he would have applied to it. It may possibly be the fungus listed on *Senecio* by Saccardo as *Phoma herbarum*, but this species is generally understood to have somewhat broader spores. Strain 6, on Vinca, may also have been included in *P. herbarum* if collected before. It can scarcely be *P. vincicola* Gonz, which has spores 10–12 × 2 μ, or *P. Kalkhoffii* Bub., with spores 5–7 × 1 μ. *P. linella* Desm. is said by Grove to be a *Phomopsis*. Strain 7 is presumably *Diplodina Sonchi* Henn. 1905; described with oblong-cylindrical, 1-septate spores 8–13 × 3–3·5 μ, on dry stems of *Sonchus asper*. Of all the above names, except *P. herbarum* which is of uncertain application, *P. solanicola* Prill. & Del. has priority. If *Phyllosticta Lonicerae* Westd. be accepted as the same species, however, it will take precedence as it dates from 1851. Much confusion exists as to the nomenclature of the *Phoma-Ascochyta* strains associated with foot rot of flax and much further study would be required before it can be decided how many of them are actually distinct. A disease apparently identical with that associated with strains 8 and 9 was described in Ireland as due to a *Phoma* sp. (Pethybridge, Lafferty & Rhynehart, 1921). According to Rost (1938) the fungus causing a similar disease in Germany is *P. Lini* Pass. with spores 3–7 × 1·5–3 μ. In his view this is distinct from *P. linicola* Marchal & Verplancke to which Pethybridge, Lafferty and Rhynehart's fungus has been referred. Rost also claimed that a strain of *P. lingam* destroyed flax seed sown in soil inoculated with it.

Clearly strains 8 and 9 represent a single fungus, differing merely in the relative proportions of one- and two-celled spores in the pycnidium at the moment of examination. According to the current classification they must be placed in *Ascochyta* or *Diplodina* and seem to agree best with the description of *Ascochyta linicola* Naumoff & Vassilievski. Inoculation experiments with flax carried out by Foister after my transfer to Kew have shown that of all the strains tested only those isolated from flax could attack flax. Evidently strains 8 and 9 represent a species distinct from the other fungi in group II.

Group III. This group contains only *Diplodina Lycopersici* Hollos, which has been repeatedly described by previous workers. For comparison with

group II a brief account of its growth on my medium is given here. The mat is at first sparse and white, with tangential dark olive-green patches among the submerged hyphae by the fourth day. By the eighth day the mat is predominantly dark olive-grey, short and close, passing radially into a short white mealy growth which fades imperceptibly into the extending margin. From below the central 2 cm. already appear almost solid black. The rest of the submerged hyphae appear olive-grey, dotted with pycnidial rudiments in rather ill-defined concentric zones. The margin is whitish with a hint of zoning.

On the whole the mat is less dense and more even than that of group II and has a hint of brown towards the centre. The margin is less crenate and the pycnidial rudiments more abundant; towards the edge of the plate they are usually conspicuously elongated and deformed. No pycnidia matured in agar cultures (Text-fig. 1 J). On sterilized potato plugs the growth is quite unlike that of strain 2. There is a very sparse aerial mat and a densely crowded layer of pycnidia, making the surface look brown, rather than grey. The sterile 'stilboid' bodies figured by Wollenweber and Hochapfel (1936) were abundant when the cultures were about three weeks old.

The spores of strain 11 were about 24 % septate in pycnidia developed on tomato stems inoculated 29 March and examined 25 May, after being kept six days in a moist Petri dish. The unicellular spores measured 4·7–9·0 × 3·3–4·5 μ, average 6·4 × 4·1 μ, and the 2-celled ones 7·6–11·6 × 4·2–5·3 μ, average 9·4 × 4·7 μ.

In addition to the small differences in appearance of the mat in culture group III differs from group II in the presence of the 'stilboid' bodies, in the different reaction on potato tubers and in its more aggressive behaviour on living tomato stems. 10 % gelatine was liquefied by it to the depth of 5 and 16 mm. in fifteen and thirty days respectively. This fungus was regarded by Grove (1935) as identical with *Phoma destructiva* Plowright emend. Jamieson. This is improbable, for all workers who have studied the two fungi in culture regard them as distinct. Klebahn (1921) differentiated them on the ground that *Diplodina Lycopersici* did not mature pycnidia in agar culture while *Phoma destructiva* did so readily, but produced no septate spores. Brooks and Searle (1921) were similarly able to distinguish between two series of cultures, one of which they regarded as *P. destructiva*, the other as *D. Lycopersici*. Wollenweber and Hochapfel (1936) similarly conclude that *P. destructiva* 'Von *Diplodina* = *Ascochyta Lycopersici* unterscheidet sich der Pilz durch die kleinern, fast ausschliesslich einzelligen Sporen und sein durchscheinend auf die Tomatenfrucht beschränkte Schadwirkung'. I was unfortunately unable to obtain an authentic culture of *Phoma destructiva* as understood by Jamieson (1915), but it is worth noting that in her experiments the fungus would not attack potato tubers whereas *Diplodina Lycopersici* does so readily. The occurrence of what he believed to be *D. Lycopersici* in potato stems in the field has been reported from Jersey by Small (1936). It may be noted, however, that the rotting of tomato fruit and production of lesions when inoculated to tomato stems are not sufficient criteria for identification of *D. Lycopersici*.

Group IV. This group contains only strain 12 from living ivy leaves.

There is at first rather sparse white aerial growth in culture, with no dark hyphae, but by the fourth day the margin of the mat is already becoming irregular. By the sixteenth day the mat has changed to a rather sparse grey growth with whitish tips. The edge is almost free from aerial mycelium, white and crenate. The submerged hyphae are chocolate coloured to blackish brown over the greater part of the culture, but only form a solid mass of colour over the central 2 cm. The mature plate six weeks old is distinguishable by its short dark grey-brown growth matting down in a reticulated fashion with only occasional paler tinges. The submerged olive-brown hyphae are still rather sparse towards the margin, but fairly evenly developed, with irregular darker and lighter zones over the central 6 cm. No pycnidia developed in plate cultures, but they are plentiful on agar slants one month old (Text-fig. 1 H). No exudate was seen, but spores obtained by crushing apparently mature pycnidia were $4{\cdot}7 \times 2{\cdot}3$ ($3{\cdot}0$–$6{\cdot}2 \times 1{\cdot}9$–$2{\cdot}8$) μ (Text-fig. 3 E). On the host the spores measured $5{\cdot}6 \times 2{\cdot}5$ ($4{\cdot}7$–$6{\cdot}2 \times 2{\cdot}2$–$3{\cdot}1$) μ, but were not very abundant.

Strain 12 liquefied 10 % gelatine to a depth of 14 and 21 mm. in fifteen and thirty days respectively. It induced no lesions when inoculated into potato tubers, swedes, tomato stems and fruit or apple fruit.

The original collection was on living leaves marked with grey spots with dark-brown indistinctly zoned margins and would undoubtedly be called *Phyllosticta hedericola* Dur. & Mont. It is noteworthy, however, that Grimes *et al.* (1932) obtained from similar lesions a fungus identified as *Phoma destructiva* which rotted tomato fruit quite readily. It would appear, therefore, that lesions of the type known as *Phyllosticta hedericola* are associated with more than one fungus.

Group V. Strain 13, isolated from a pycnidium on a fallen ash fruit, forms a rather loose white aerial mat, shorter towards the edge, but without a clearly differentiated extending margin. Growth was slower than in most strains studied and at the end of four days there was only a dense white dome of hyphae. By the eighth day there was a dense white mat, up to 5 mm. thick, somewhat loose on the surface and turning light grey-brown over the central portion. From below the central area was seen to be mottled all over with shades of chestnut brown, leaving a sharply defined uneven white margin 2–3 mm. wide. After a fortnight growth had ceased. There was a finely lobed narrow white margin to a dense yellow-brown mat mottled brown below as on the eighth day. The marginal lobes were rounded, not dendritic as in group II. Older cultures differed only in the presence of white tufts of aerial mycelium, especially towards the margin. Pycnidia were not formed in any plate culture, but matured with pink exudate in 14 days round the holes in an agar slant from which inoculum had been taken (Text-fig. 1 M).

On oatmeal-agar strain 13 attained a diameter of 44 mm. in twelve days, forming a pure white, close mat, light grey only over the central 15 mm. At this time it was still colourless below except for a grey-brown tint in the central 2 cm. When five weeks old the plate was covered with a close white aerial mat beginning to collapse without further discoloration. Blackish brown submerged hyphae occupied only the central 2 cm., apart from

a narrow irregular zone of about 65 mm. diameter, apparently marking a stage at which growth had been temporarily checked. There were no pycnidia and there was no hint of red in the culture.

The submerged hyphae from malt agar cultures were light brown, with no tinge of olive under the microscope, mostly about 6 μ wide, swelling occasionally to 8 μ, and composed of elongated cells with few oil globules. There were no chlamydospores.

On tomato stems the pycnidia were about 200 μ across, distinctly ostiolate, but without necks. The hyphae in the surrounding tissue were up to 10 μ broad, closely septate and hyaline. Spores from these pycnidia were $7{\cdot}7 \times 4{\cdot}0$ $(5{\cdot}6–10{\cdot}4 \times 3{\cdot}3–4{\cdot}2)\,\mu$ elliptical to subcylindrical and non-guttulate. Occasional 1-septate spores measured about $10{\cdot}4 \times 4{\cdot}8\,\mu$. In the pink exudate from pycnidia on a malt agar slant the spores were biguttulate $6{\cdot}8 \times 3{\cdot}7$ $(5{\cdot}9–8{\cdot}7 \times 3{\cdot}1–4{\cdot}2)\,\mu$ and septate spores were not seen (Text-fig. 3 E).

On Doon Star tubers strain 13 formed lesions 4·5 mm. across (2–7 mm.) in eight out of ten inoculations and similar small localized lesions on swede roots. Of three inoculations to living tomato stems one failed, the others yielded lesions which attained a maximum size of 9×2 and 9×4 mm. respectively and bore a few mature pycnidia. The fungus rotted green tomato fruit, giving lesions 11 and 27 mm. across in seven and fifteen days respectively. On apple the lesions did not exceed 5 mm. 10 % gelatine was liquefied to a depth of 7 and 13·5 mm. in fifteen and thirty days respectively.

This fungus cannot be *Phoma samararum* Desm., for according to Wollenweber and Hochapfel (1936) that species is a *Septoria* with 0-septate spores $7–12 \times 1{\cdot}7–2{\cdot}2\,\mu$ and 1-septate spores $10–15 \times 1{\cdot}7–2{\cdot}2\,\mu$. It appears, however, to resemble closely their description of *P. aceris-negundinis* Arcangeli which, in turn, differs only slightly from *P. striaeformis* Dur. & Mont. isolated by them from very diverse hosts. The latter is said to include among its synonyms *P. Bismarckii* Kidd & Beaumont, described from rotting apples in England.

Group VI. Included in this group are strains 14–16 inclusive. The following description of growth in culture is based primarily on the behaviour of strain 15.

After four days there is a rather loose white mat rising gently from the margin to the centre of the mat. By the eighth day the very short white mat has developed small depressions on its surface and has a hint of greyness at the centre. There is diffuse grey mottling of the submerged growth in the central 20 mm. On the fifteenth day the mat is still white, faintly grey at the centre, but is closely pitted all over in a very characteristic fashion so that the whole surface of the culture appears reticulated. By this time the submerged mycelium has become light olive-grey over the central 25 mm. and pycnidia are plentiful, bearing salmon-pink exudate. As a rule they tend to be arranged in radiating rows instead of in concentric zones, as though due to sectoring. After a month's growth there is no change in the general appearance except that an olive-brown tint has spread over the greater part of the submerged growth (Pl. II, fig. 8).

Strain 14 (Text-fig. 1 N) differed only in the submerged mycelium

turning olive-grey only from the fifteenth day onwards. Strain 16 appeared identical with strain 15.

The spore measurements of these three strains are given in Table 5, with the gelatine liquefaction data for strains 14 and 15. Strain 16 was not grown on gelatine.

Table 5. *Spore measurements of strains* 14, 15 *and* 16

Strain No.	Substrate	Unicellular spores	2-celled spores	Depth of gelatine liquefied in 15 days	Depth of gelatine liquefied in 30 days
14	Malt agar plate 1 month old	7·4 × 3·4 (5·9–9·6 × 2·5–4·2) μ	11·2 × 4·2 μ	0	15 mm
15	Malt agar plate 18 days old	7·2 × 3·4 (5·0–10·1 × 2·8–4·2) μ	11·2 × 5·0 μ	Trace	7 mm.
	Stem of *Centaurea Scabiosa*	7·0 × 4·0 (6·2–7·9 × 3·4–4·5) μ	—		
16	Malt agar plate 7 days old	7·6 × 3·4 (5·9–9·3 × 2·8–3·9) μ	11·9 × 5·8 (9·8–14·7 × 4·8–6·5) μ	Not tested	
	Living leaves of *Ribes Grossularia*	6·3 × 3·2 (5·0–7·6 × 2·5–3·6) μ	—		

The spores are always broadly elliptical, biguttulate or with groups of polar granules (Text-fig. 3 E). Septate spores were very few in the exudate of strains 14 and 15, barely 1 % in strain 16. Occasional rounded chlamydospores about 20 μ across occurred in the submerged hyphae of strains 14 and 15.

Strains 14 and 15 induced no lesions on potato tubers, tomato stems or fruit, swede roots or apple fruit. Strain 16 gave similarly negative results on potato, tomato and apple fruit, but was not tested on swedes or tomato stems.

Strain 16 would certainly be classed as *Phyllosticta Grossulariae* Sacc. and there seems every reason to regard strains 14 and 15 as identical with it, though a fungus corresponding to strain 15 was apparently included by Saccardo under *Phoma herbarum* West. Strain 14 was obtained from immature pycnidia without spores on a fallen fruit of *Fraxinus excelsior*.

Group VII. This includes strains 17 and 18, both isolated from the tissues of potato tubers showing superficial necrosis.

On malt-agar plates there is at first a dense white mealy growth, below which olive-coloured hyphae are already apparent by the third day. By the fourth day there is a distinctly differentiated marginal zone white below, with very sparse whitish aerial growth above, about 4 mm. wide. Within this is a dense taller grey mat, dark olive-grey below. A mature culture shows a rather short dense mealy olive-grey mat, paling towards the margin where it passes into a narrow pale extending zone only 1–2 mm. wide (Pl. II, fig. 1). Such a culture appears black at the centre below, passing into olive-grey towards the margin.

On sterilized potato plugs there is a dense dark grey growth, olive-coloured at the dry upper end. A crust of pycnidia forms on the surface of the tissue within three weeks from inoculation and exudes a copious grey slime of conidia.

Pycnidia did not appear in the original mycelial transplants on malt agar, but when a brush streak was made on a malt agar plate with a suspension of conidia from a potato plug culture a crowded band of pycnidia developed along the streak (Text-fig. 1 L). Below these the medium appeared black owing to the submerged hyphae and chlamydospores, but on each side of the streak remained a clear band, each 3–4μ wide and 8 mm. apart. The rest of the plate became covered with the normal mat described above.

Both fungi produced abundant and characteristic chlamydospores, mostly in pairs or short chains, and measuring individually about 7–13 × 5–10μ (Text-fig. 3 D). In some instances these chlamydospores are produced in such numbers on infected potato tubers as to give rise to a coal-black layer immediately under the skin.

Strain 18 was received as a single spore culture from Dr A. R. Wilson. Single spore isolations of strain 17 made from the potato plug culture did not differ in appearance from the original mycelial isolate.

Inoculation experiments showed both strains to be non-parasitic to all the experimental hosts with the possible exception of apple fruit, on which minute round lesions 3–4 mm. in diameter developed with both fungi. Strain 18 had been identified by Dr Bisby as *P. eupyrena* Sacc. as interpreted by Wollenweber, and it is interesting to note that the latter reported his isolate to cause rotting of apple, cucumber and potato. It is curious, however, that Wollenweber and Hochapfel, writing subsequently, did not mention *P. eupyrena* among the *Phoma* species causing minor rots of fruit. Wollenweber's original isolate was regarded by him as the cause of blackish pimples on potato skins (Wollenweber, 1920). As Shapovalov (1923) has shown, however, these were obviously the disease now known as Skin Spot and the *Phoma* must have been a secondary invader. Shapovalov, however, contributed to the confusion by confounding Skin Spot with the early stages of Powdery Scab. Exuded pycnospores of strain 17 on potato plugs measured 3·4–5·0 × 2·2–3·6μ, mean 4·3 × 2·5μ (Text-fig. 3 E). Those obtained by crushing pycnidia developed on the host were, as usual, somewhat smaller, with mean size 3·1 × 1·9μ. Septate spores were not observed. On 10% gelatine strains 17 and 18 behaved exactly alike, liquefying 6·5 and 12 mm. in fifteen and thirty days respectively. The identity of Wollenweber's fungus, with spores 4–6 × 1·7–2·3μ, with Saccardo's which had spores 4 × 1·5μ seems open to question.

Group VIII. This contains only strain 19, but an identical fungus was isolated from similar pycnidia on *Anthriscus sylvestris* in Corstorphine.

In Petri dish cultures this strain formed a close, short pure white mat with a mealy surface (Pl. II, fig. 2). There was no zoning and no discoloration of the aerial mycelium until it began to degenerate and turn light grey when about one month old. The marginal extending zone was very narrow and passed imperceptibly into the main body of the mat. The submerged mycelium showed a faint greenish brown hue at the centre on the seventh day and the colour slowly darkened to olive-grey and ultimately black at the centre. Ill-defined concentric lighter and darker zones were apparent by the eighteenth day. Pycnidia, at first yellow-brown,

ultimately black, appeared in the central area when about a week old (Text-fig. 1 K). There were no chlamydospores.

Spores from the original pycnidium on *Heracleum* measured 7·0–10·0 × 2·5–3·5 μ; those from the pink exudate of pycnidia on a two months old Petri dish culture measured 7·8–11·6 × 2·5–3·6 μ, mean 10·3 × 3·2 μ, with occasional two-celled spores 11·2 × 4·2 μ (Text-fig. 3 E).

Strain 19 induced no lesions on any of the experimental hosts. This fungus is obviously *Phoma complanata* Desm. and is distinguished from all the preceding groups by the massive character of its pycnidia, the wall of which in culture consisted of about 6 layers of cells instead of 2–3 layers.

Group IX. Group IX contains five strains, numbers 20–24 inclusive, all characterized by massive black pycnidia, small cylindrical spores, cream-coloured exudate and slow-growing close grey mycelial mats in culture. The following description applies to strain 20; the mat produced by the other strains differed in detail as indicated below.

Table 6

Strain No.	Substrate	Spore size	Depth of gelatine liquefied in 15 days	Depth of gelatine liquefied in 30 days
20	Dead stem of *Urtica dioica* Malt-agar slant 12 weeks old	4·7 × 1·8 (3·9–5·4 × 1·6–1·9) μ 4·3 × 1·5 (3·6–4·8 × 1·4–1·9) μ	7 mm.	14 mm.
21	Dead stem of *Sisymbrium officinale* Malt-agar plate 8 weeks old	4·6 × 1·5 (4·0–5·3 × 1·4–1·6) μ 5·1 × 1·5 (4·2–5·6 × 1·1–2·2) μ	Trace	15 mm.
22	Dead umbelliferous stem Malt-agar plate 4 weeks old	4·5 × 1·8 (3·6–5·4 × 1·6–2·0) μ 5·2 × 1·7 (4·2–6·2 × 1·4–2·5) μ	Trace	15 mm.
23	Dead stem of *Lapsana communis* Malt-agar plate 4 weeks old	5·0 × 1·7 (4·5–5·5 × 1·5–2·0) μ 5·1 × 1·5 (4·2–6·7 × 1·1–2·2) μ	5 mm.	19 mm.
24	Dead stem of *Anthriscus sylvestris* Malt-agar slant	5·5 × 2·1 (4·5–6·8 × 1·6–2·5) μ 4·7 × 1·6 (3·6–5·9 × 1·4–2·0) μ	Trace	14½ mm.

By the seventh day there was a dense grey mound of aerial mycelium, about 3 mm. thick, over the inoculum, surrounded by a short, close, olive-grey mat with a very narrow, paler, extending zone (Pl. II, figs. 4–7). The culture already appeared an even olive-grey colour from below. This appearance was maintained throughout the life of the culture except that the mat tended to become somewhat mealy due to the presence of closely crowded short grey tufts on a darker basal layer of hyphae. No chlamydospores were seen, but ripe pycnidia were present by the eighteenth day. Very few were produced, however, and in many subsequent agar slant cultures none was found.

Strain 21 differed in showing distinct colour zoning in the submerged growth and in producing more pycnidia. Strains 22 and 23 were similar to 21, but had numerous pycnidia in concentric zones; number 22 had more and taller aerial mycelium and less colour in the submerged hyphae than 23 (Pl. II, fig. 9). Strain 24 was intermediate in appearance between 22 and 23, rather slower growing than either, and bore no pycnidia on the Petri-dish cultures. The spore dimensions and gelatine liquefying capacity of the five strains are set out in Table 6.

Septate spores were not observed in any strain of this group (Text-fig. 3 E).

Strain 24 was isolated from a pycnidium which formed one of a group round which the surface of the host was stained a faint pink colour (Text-fig. 2 B). No pink pigment was produced by this strain in culture, either in the hyphae or in the medium and the association with staining of the host was probably fortuitous.

The original collection of strain 22 was characterized by very long beaks to the pycnidia (Text-fig. 2 C). This character was retained in culture, where it was exhibited to an equal extent by strain 24 (Text-fig. 2 E, F). The remaining strains produced pycnidia with distinct but usually shorter beaks (Text-fig. 2 G). All strains gave uniformly negative results in inoculation experiments with all the differential hosts.

Strain 20 is *Phoma acuta* Fckl. (Text-fig. 2 D). The remaining strains are clearly closely allied to it and there seems little justification for attempting to separate strains 21 and 23 on morphological or other grounds. The two strains from Umbelliferae may possibly be differentiated on a basis of pycnidial shape, though this seems to be a somewhat variable and unreliable character. On the whole it seems best to regard all five fungi as representing a single species widespread in nature on dead herbaceous stems. Strain 23 may be *Phoma Lampsanae* Karst., but it is doubtful if numbers 21, 22 and 24 have been described as distinct species. Number 24 in general appearance suggests *P. sanguinolenta* Grove, but has smaller, narrower spores.

Group X. Strains 25–27 inclusive are all easily recognizable in culture by their abundant pycnidia and sparse aerial mycelium. In spite of some variation in size and number of pycnidia they appear to form a natural group. The following description applies primarily to an early transfer of strain 25. By the fourth day the culture had attained a diameter of 15 mm. with no aerial hyphae, but was already covered with pycnidia. On the seventh day there was a little aerial mycelium, scarcely visible to the naked eye. The whole surface of the culture was covered with yellow-brown pycnidia (Pl. II, fig. 3). On the ninth day a few short white aerial tufts were present. The central portion of the growth was covered by a yellow-brown crust of pycnidia; surrounding this was a zone of less crowded darker pycnidia followed by a marginal area 8 mm. wide in which fructifications had not yet developed. There were no dark submerged hyphae and the only changes in appearance of the culture with age were more pronounced zoning in density of the pycnidia, change in their colour to dark brown with a pinkish ooze of spores and more abundant clumps of white aerial mycelium which ultimately turned grey-brown.

Strain 26 looked identical except that the pycnidia appeared slightly smaller (Text-fig. 1 R; Pl. II, fig. 10). No chlamydospores were found in either fungus.

As shown by the photographs these early transfers very closely resembled *P. hibernica* Grimes *et al.* (1932) and a culture of strain 26 sent to Prof. Grimes was accepted by him as being probably that species.

Subsequent transfers of numbers 25 and 26 differed from the above description, however, in producing fewer pycnidia and more white aerial

mycelium. Moreover, old plates developed a certain amount of submerged olive-brown mycelium. Hence when grown on the same plates with *P. hibernica* they appeared quite distinct from it. Presumably this change was due to staling. A fresh isolate of strain 25, inoculated with *P. hibernica* to opposite sides of the same Petri dish, showed the two to grow at exactly the same rate and to appear alike except that this time number 25 produced far fewer pycnidia (Pl. III, fig. 1). Hence the general aspect of the culture was whitish whereas that of *P. hibernica* appeared pink at the centre from the extended conidia and yellow brown towards the margin owing to the crowded immature pycnidia. Older Petri-dish cultures of *P. hibernica* developed towards the margin extensive sectors carrying few pycnidia and with considerable light grey-brown aerial growth. Obviously there can be a great deal of variation in the relative proportions of pycnidia and aerial mycelium and it seems unwise to attempt to separate the three strains on this character alone. Spore sizes are indicated in Table 7.

Table 7. *Spore sizes and gelatine liquefaction by strains* 25–27

Strain no.	Substrate	Spore dimensions	Depth of gelatine liquefied in 15 days	Depth of gelatine liquefied in 30 days
25	Dead stem of *Urtica dioica*	5·1 × 2·0 (3·3–5·9 × 1·6–2·2) μ		
	Malt-agar plate 2 months old	5·8 × 2·9 (4·5–6·8 × 2·2–3·9) μ	10 mm.	19 mm.
	Malt-agar slant 14 days old*	5·8 × 3·1 (4·7–6·8 × 2·8–3·6) μ		
26	Dead stem of *Angelica sylvestris*	6·6 × 2·8 (5·0–7·3 × 2·0–3·1) μ		
	Malt-agar plate 5 weeks old	6·4 × 3·2 (5·3–7·6 × 2·5–4·2) μ	18 mm.	30 mm.
27	Malt-agar slant 14 days old	7·5 × 3·7 (6·7–9·3 × 3·3–4·5) μ	10 mm.	17 mm.
	As cited by Grimes *et al.*	5–7 × 4 μ		

* These figures apply to spores of 'normal' elliptical shape. About 25 % of those in the exudate on this particular slant were irregular or semiglobose and measured about 6·8 × 6·0 (5·9–7·6 × 5·3–6·8) μ (Text-fig. 3 E).

All three strains were completely non-pathogenic to all the differential hosts.

Strain 25 seems to be *Phoma Urticae* Sch. & Sacc. Strain 26 probably corresponds to five collections of a *Phoma* on *Angelica* in the Grove herbarium, placed by him under *Phoma oleracea* Sacc. It has, however, slightly larger spores than the pycnidia examined from Grove's material, which had spores 4–5 × 1·5–2 μ. Whether *P. hibernica* is identical with either or both the other strains of this group is rather doubtful. The culture received from Grimes under that name had larger spores than either numbers 25 or 26. On the other hand, the diagnosis of *P. hibernica* states it to have spores 5–7 × 4 μ, i.e. distinctly shorter than those measured from strain 27. Bisby *et al.* (1933), on the other hand, obtained a strain of this type with narrower spores, 4–7 × 2–3 μ. It would appear that the spore size is not constant and that much weight cannot be placed on the differences brought out in Table 7.

Prof. Grimes kindly suggested comparative cultures on a special medium to settle the point, but as the medium included much cream it could not be used during the war. The relationship of *P. hibernica* to other species can scarcely be regarded as determined until the source from which it con-

taminates cream and milk products is discovered. So far, the species has been reported from two localities. It is evidently common at Cork in milk, cream, butter and water, and Bisby *et al.* (1933) encountered it in butter in Manitoba.

Group XI. Phoma nebulosa, as represented by strain 28, is not uncommon on the upper part of dead *Urtica dioica* stems (Text-fig. 2 N) and usually occurs side by side with *P. Urticae*. Owing to the tendency of the latter to vary in culture as regards the quantity of aerial mycelium one is tempted to regard *P. nebulosa* as merely the extreme mycelial form of group X. Its behaviour in culture, however, is so constant that the suggestion seems unwarranted. There was no possibility of confusing the most extreme mycelial phase of strain 25 or 26 with strain 28, owing to the presence in the latter of dark submerged mycelium from the outset.

By the fifth day a culture of the latter consists of a dense white mass of aerial mycelium covering the central 2 cm., with sparse hyphal development on the remainder of the mat. Olive-brown submerged mycelium was already present over the central 1 cm. By the eighth day almost the whole culture was covered with a dense woolly white growth, sparse over the marginal centimetre and fading into the extending edge which was already crenate (Pl. III, fig. 2). Scattered pycnidial rudiments were visible towards the centre of the mat. Further growth led to little change in appearance except that the submerged hyphae became dark brown at the centre with a few irregular lighter and darker concentric zones towards the margin. On a mature Petri-dish culture the woolly aerial growth, continuous at the centre, tended to become broken up into islands towards the margin, so that the dark submerged hyphae were visible between them.

On sterilized potato plugs there was the same dense pure white growth covering a layer of chocolate to dark grey-brown mycelium on the surface of the plug and along the lines of contact with the glass.

No pycnidia matured either in Petri-dish cultures or on agar slants, but they were very abundant on the potato plugs within 14 days of inoculation (Text-fig. 2 O).

The pycnidium from which strain 28 was isolated contained rather irregularly cylindrical spores with rounded ends, occasionally pointed at one end and sometimes three-cornered in shape (Text-fig. 3 E). The non-septate spores measured $9{\cdot}3 \times 3{\cdot}7$ $(7{\cdot}6–11{\cdot}3 \times 2{\cdot}8–4{\cdot}5)\,\mu$. Among these were about 2 or 3 % of septate spores measuring $11{\cdot}4 \times 4{\cdot}3$ $(9{\cdot}3–13{\cdot}2 \times 3{\cdot}6–5{\cdot}0)\,\mu$. Spores crushed from pycnidia in a potato plug culture fifteen days old were cylindrical with rounded, often slightly swollen ends, mostly biguttulate, $9{\cdot}3 \times 3{\cdot}4$ $(7{\cdot}5–11{\cdot}3 \times 2{\cdot}8–3{\cdot}9)\,\mu$. Other pycnidia on the same piece of discoloured nettle stem contained non-septate spores up to $11 \times 2\,\mu$. Isolations from these yielded the same type of culture as strain 28.

P. nebulosa liquefied 10 % gelatine to the extent of 11 mm. and 24 mm. in fifteen and thirty days respectively. It induced no lesions when inoculated to any of the experimental hosts.

Group XII. This contains only strain 29 isolated from a pycnidium on a dead figwort stem. By the third day there was already dark olive-grey submerged mycelium at the centre of the culture, covered by a close short

white mealy growth. On the eighth day there was a hint of greyness at the centre of the aerial mat with vague zoning towards the margin (Pl. III, fig. 8). A few scattered pycnidia were present, but the dark colour had not extended in the submerged mycelium. By the twelfth day, however, greyish zone lines were apparent below and pycnidia were scattered over most of the culture. After seven weeks the aerial growth was still white, though beginning to break down. Pycnidia were plentiful over the central 50 mm., though more numerous in two zones. Outside this area were two more scattered belts of pycnidia. Slight development of dark submerged hyphae had taken place around the pycnidia, but not enough to discolour the lower surface as a whole. Pycnidia of this strain in culture tended to occur fused together to form large, irregular, multilocular masses more or less conical in shape and from 1 to 2 mm. across (Text-fig. 3 B). The exudate was pale pink. Spores from a month old culture measured $6{\cdot}0 \times 2{\cdot}0$ ($4{\cdot}7$–$7{\cdot}3 \times 1{\cdot}4$–$2{\cdot}5$) μ (Text-fig. 3 E). Those on the host were rather narrowly cylindrical, with rounded ends, sometimes slightly curved, biguttulate $5{\cdot}5 \times 2{\cdot}1$ ($4{\cdot}5$–$6{\cdot}5 \times 1{\cdot}9$–$2{\cdot}5$) μ. The fungus was not parasitic to any of the usual hosts. It liquefied 10% gelatine to a depth of 12 mm. and 26 mm. in fifteen and thirty days respectively. This strain is evidently a form of *Phoma oleracea* Sacc. and five similar collections on *Scrophularia* occur in the Grove herbarium under that name or as var. *Scrophulariae* Sacc.

Group XIII. Strain 30, from a dead goldenrod stem, has spores rather similar to those of group IX, but appears sufficiently different in culture to warrant its retention as a separate group. Also the pycnidia, both on the host and in culture, were quite unlike those of *P. acuta* (Text-fig. 2 H, J). They were far less massive and on the goldenrod stem superficially resembled those of group XII on *Scrophularia*, but with thinner walls (cf. Text-fig. 3A).

The aerial mat was at first dense, pure white, with an evenly rounded surface, but by the fifth day the centre was turning grey and a dark olive-grey hue with darker spots had spread over the middle 2 cm. of the submerged mycelium. By the eighth day the culture was easily distinguished from those of any other strain by its dense woolly aerial mat, the same grey as strain 20, but forming a very flat cone with the margin paling into white (Pl. III, fig. 4). Almost the entire lower surface of the culture appeared dark olive-grey, with a narrow, rather sharply defined, white margin. There were no pycnidia on Petri-dish or agar-slant cultures.

On potato plugs there was the same light grey woolly growth, almost white in places, covering an olive-grey layer which appeared almost black along the lines of contact with the glass. Small pycnidia were very abundant after about a fortnight's growth (Text-fig. 2 J).

The spores of the original collection were 5–$7 \times 2{\cdot}0$–$2{\cdot}5\,\mu$; those on the sterilized potato tissue were $5{\cdot}5 \times 1{\cdot}5$ ($4{\cdot}2$–$6{\cdot}2 \times 1{\cdot}0$–$2{\cdot}5$) μ (Text-fig. 3 E). 10% gelatine was liquefied to a depth of 10 mm. and 19 mm. in 15 and 30 days respectively. The following appear to be the only *Phoma* spp. recorded on *Solidago*:

P. herbarum West f. *Solidaginis* Sacc. with spores 7–9×3–$4\,\mu$.

P. Solidaginis Cke, with spores 9–$10 \times 2\,\mu$.

Neither of these appears to agree well with strain 30. There is also a *Phyllosticta Solidaginis* Bres. with spores 5–6 × 2 μ, but it is idle to speculate on a possible relationship with such a form. Strain 30 cannot therefore be named at present.

Group XIV. The fungus from goose-grass bore some resemblance in culture to Group I, but is easily distinguished from it by other characters. Growth was at first thin, sparse and white. After one week the aerial mycelium was still very thin, but there was an olive-brown tinge to the central 2 cm. of the lower side of the culture. By the twelfth day the whitish marginal zone was already somewhat crenate and surrounded a rather thin, short, chocolate-coloured aerial mat. The submerged mycelium was olive-brown to almost black and formed a fibrous radiating network, not a solid mass of colour (Pl. I, fig. 3). By the eighteenth day there was irregular wavy zoning very like that of Group I.

The submerged hyphae were rather broad, mostly 5–9 μ across, dark brown and crowded with oil globules as in *P. foveata*. No chlamydospores were seen. Pycnidia were scattered rather sparsely over the culture and produced a whitish exudate when mature. On the host the spores were cylindrical or slightly curved, with rounded ends, mostly biguttulate, and 8·5 × 3·1 (7–9·8 × 2·8–3·4) μ in size. As in strain 25 the spores exuded from pycnidia in culture tended to be irregular and swollen and measured 5·8 × 3·8 (4·5–7·6 × 3·1–4·8) μ (Text-fig. 3 E). Strain 31 liquefied gelatine to the extent of 13 mm. and 24 mm. in fifteen and thirty days respectively.

From *P. foveata* this strain differs in its somewhat larger spores, different coloured exudate and inability to produce lesions on potato, swede, tomato stems or fruit. Minute circular lesions were produced on apple fruit, but no rot developed. It is rather difficult to decide what to call this strain. The material labelled *P. herbarum* f. *Galiorum* Sacc. in Grove's herbarium, though superficially similar, has quite different elliptical spores, mostly 4–5 × 2–3 μ. When re-examined nine months after collection the Berwickshire material showed a few of the larger spores to have become 1-septate. Hence the fungus is probably the same as that identified by Grove with *Diplodina Gallii* (Niessl) Sacc., collected on *G. Mollugo*, Polperro, Cornwall, with spores 8–10 × 3 μ, though almost all the spores of that collection are now distinctly septate.

Group XV. Strain 32, from a pycnidium on gooseberry twigs, differed from all other strains encountered in the small size of its spores. Growth in malt-agar culture was extremely slow, not exceeding 13 mm. in diameter in seven days. After fifteen days there was a dense, rather thick, olive-green mat passing laterally into a yellow-green zone and finally a rather thin narrow white margin. Fine whitish tufts of hyphae were scattered throughout (Pl. III, fig. 7). The lower surface was dark olive-grey at the centre, fading to an almost white margin. When one month old there was still a dense olive-grey dome of hyphae over the inoculum, surrounded by a narrow depressed zone. The remainder of the mat was about 2 mm. thick, light olive-grey and very close and even or with a finely reticulated surface. Towards the margin the colour changed to yellow-green. The very dark olive-grey hue of the submerged mycelium persisted at the centre, sur-

rounded by concentric zones of darker and lighter hue. A few black, globose, ostiolate pycnidia about 200 μ across were scattered over the mat (Text-fig. 2 L). The pycnidial exudate was white. Submerged hyphae were composed of short dark olive-brown cells, but no distinct chlamydospores were seen. Strain 32 liquefied gelatine more slowly than any other, except perhaps strain 34, viz. to the extent of only $6\frac{1}{2}$ mm. in thirty days.

The spores on the host were rod-shaped, about $3 \times 1\,\mu$. In culture they measured $3{\cdot}5 \times 1$ $(2{\cdot}5–5{\cdot}0 \times 1)\,\mu$ (Text-fig. 3 E). Strain 32 also differed from the others in having conidiophores considerably longer than the spores, up to about 16 μ long. This suggests that it was a *Dendrophoma*, but branching of the conidiophores could not be detected. In some features it resembles Wollenweber and Hochapfel's description of *D. faginea* Ferraris which, however, apparently tends towards production of a brown colour in the lower side of the culture. Strain 32 was non-parasitic on potato, swede or tomato. On apple fruit it induced small circular lesions not exceeding 5 mm. in diameter.

Strain 32 is identical with the fungus preserved in Grove's herbarium under the name *Ascochytella Grossulariae* Died., on gooseberry tips from Lambourne Hill, West Cornwall, 17 April 1933, which has rod-shaped spores $3 \times 1\,\mu$ and conidiophores about 10 μ long.

Group XVI. Strain 33 was clearly a form of *Phoma lingam* (Fr.) Desm., a species which has been repeatedly described in culture and need not be dealt with in detail here. Growth was at first dense, short, white and mealy, later turning grey above and dark olive-grey below. The pycnidial exudate was amethyst coloured and consisted of non-septate spores which measured $4{\cdot}3 \times 1{\cdot}9$ $(3{\cdot}3–5{\cdot}4 \times 1{\cdot}6–2{\cdot}2)\,\mu$.

Gelatine liquefaction was unusually rapid, 24 mm. in fifteen days, though bacterial contamination could not be detected. Strain 33 produced no lesions on any host except swede, on which it gave rise to a rot, slow at first, but ultimately rapid, especially in the outer layers of the cortex.

Group XVII. Strain 34 was Brooks and Searle's original isolation of *Phoma alternariacearum*, kindly supplied by Prof. Brooks. This was originally isolated from a rotten tomato fruit purchased in Bristol in 1916 so that it had been maintained in culture for twenty-eight years. It is therefore not surprising that it appears to have lost its ability to cause a rot of tomato fruits. Growth in culture on malt agar corresponded fairly well with Brooks and Searle's description of its behaviour on modified Dox agar (Brooks & Searle, 1921, p. 181, Form C). After four days there was a short thin whitish mat already bearing abundant pycnidia (Text-fig. 2 M). By the eighth day the thin aerial growth was turning grey-brown. There were no dark submerged hyphae, but zoning was apparent in the arrangement of pycnidia. Older cultures showed no change in general appearance apart from the production of sectors with more or less numerous pycnidia (Pl. III, fig. 9).

The characteristic chlamydospores were noted in the aerial mycelium; they varied greatly in size, mainly from $20–50 \times 10–25\,\mu$ (Text-fig. 3 C). The pycnidial exudate was pink and contained ellipsoidal conidia, sometimes slightly pointed at one end, mostly biguttulate and measuring

6·2 × 2·9 (5·0–7·3 × 1·9–3·6) μ (Text-fig. 3 E). This strain liquefied only 7 mm. of gelatine in 30 days.

According to Wollenweber and Hochapfel (1936) this is a synonym of *P. glomerata* (Corda) Wr. & Hochl.

Discussion

The traditional allocation of pycnidial fungi to the form-genera *Phoma* or *Phyllosticta* and to *Diplodina* or *Ascochyta* according to whether they are collected on stems or leaves has long been recognized to be irrational. That it is retained is a tribute merely to its convenience and a confession of the necessity of grouping for easy reference the innumerable names applied in the literature to this group of Coelomycetes. In addition it is becoming evident that generic distinctions based on the presence or absence of a septum in the small spores of this group of fungi are not strictly valid. Thus Brooks and Seale (1921, p. 184) remark that 'In studying the various forms of group A [ultimately classified by them as *P. destructiva* and *D. Lycopersici*] it was found that these showed great variability in characters which are generally looked upon as specific, such as size of spores, septation of spores, guttulation and shape of spores, and one was forced to the conclusion that a number of so-called species in genera like *Phoma*, *Ascochyta* and *Diplodina* are nothing more than varieties of one and the same fungus.' Sattar (1934) similarly found that no sharp distinction could be drawn between Sphaeropsidales with hyaline continuous spores and those with 1-septate spores of similar shape, i.e. between the twin-genera *Phoma-Phyllosticta* and *Diplodina-Ascochyta*.

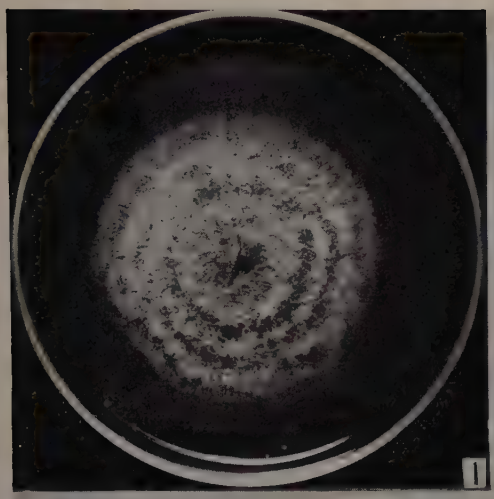
So many are the difficulties, however, in attempting to introduce some order among the vast number of host-species at present allotted to these genera that taxonomists are naturally reluctant to relinquish such a convenient generic character as the presence or absence of a septum in the spores. Thus Wollenweber and Hochapfel (1936), though admitting the tendency of most '*Phoma*' species to produce a few septate spores, attempted to define *Phoma* as having not more than 5 % of these. In their view 'The spores of many true *Phoma* species are not altogether one-celled, but there occur ±5 per cent 1 (2–3) septate ones, as for example in *P. glomerata*, *P. prunicola*, *P. ellipticum*, *P. Mori*, *P. striaeformis*, occasionally also in *P. destructiva*, just as also in many other species not described here, such as *P. sarmentella* Sacc., *P. nebulosa* (Pers.) Berk. and *P. Libertianae* Speg. & Roum. Because they form a normal though sparsely represented component of the spore mass they must be taken into consideration in future descriptions of the genus *Phoma*. Fungi with generally about 50–100 per cent. of the spores septate are allotted to the *Hyalodidymae* (*Ascochyta*).' Clearly this distinction is difficult to apply in practice, since it implies the absence of intermediate forms with from 5 to 50 % of the spores septate, though, as shown above in Group II, such forms are of common occurrence. Sattar (1934) found *Ascochyta pinodella* to have from 5 to 50 % of the spores bilocular on the host whilst in culture it produced only unicellular spores and hence was a *Phoma* or, as he calls it, a *Phyllosticta*. On the other hand, *Phyllosticta Rabiei*, which had at most 5–10 % of the spores bicellular, was

transferred by Sattar to *Ascochyta* because the spores became two-celled during germination. In attempting to solve the difficulty he concludes that 'one should, in my opinion, consider only spores obtained from the host'. Thus fungi like *P. hibernica*, only known in artificial cultures from contaminated butter and cream, could not be allocated to any genus, inasmuch as their host in nature is unknown. In practice it appears that a writer who has been working primarily with mainly continuous-spored species tends to ignore a considerable degree of septation in obviously related forms and allots them all to *Phoma*. Conversely a person interested in 'typical' species of *Ascochyta* seizes on the presence of an occasional septum in related species as an excuse to include them all in the same genus. Probably no great harm results from such procedure as long as it is generally recognized that the classification is merely a matter of convenience, and even of personal prejudice, and that a fungus cited in the literature under one generic name may have its closest allies listed under another. No more logical classification can be proposed until the species are better known. Before defining genera it is necessary to define the limits of the species they are to contain. It is in this connexion that the existing position is most alarming. The experiments reported above, though carried out with only thirty-four isolations, afford evidence that:

(1) The same fungus may be found in the present classification under several different names and probably in different genera ; see for examples groups II and VI. Wollenweber and Hochapfel (1936) obtained even more striking evidence in this connexion. Thus under *Phoma seriata* (Pers.) Wollw. & Hoch. they cite fourteen synonyms in five genera, not including the obsolete '*Sphaeria*'. Under *Ascochyta pirina* (Fr.) Pegl. they cite three species of *Phoma*, one of *Diplodina* and one of *Clisosporium*.

(2) The same name may be given to quite different fungi. This is not an unexpected discovery in the case of ill-defined species such as *P. herbarum* and *P. oleracea*, but it appears to be also the case with *Phyllosticta hedericola*. Grimes *et al.* (1932) have shown that one form of this host-species is indistinguishable from *Phoma destructiva*. The writer, on the other hand, has isolated under that name a fungus incapable of attacking tomato fruit, almost the only valid character, other than spore size, on which *P. destructiva* was founded.

(3) Fungi capable under favourable circumstances of parasitizing economic plants such as potato, tomato and apple may be found in nature as saprophytes on herbaceous weeds, where their presence has hitherto been unsuspected. Though the diseases in question are of minor significance, this discovery is of interest as indicating that, for example, gangrene-type lesions in potato may be expected to occur even when clean seed is planted in virgin soil. Clearly before plant pathologists apply names to minor parasites of this kind they must make an exhaustive study of the already described saprophytic species occurring in the same locality. What is urgently needed is a reinvestigation of the small-spored Sphaeropsidales, based on isolations from material matched with the existing host-species and subsequently grown for comparison under uniform conditions in artificial culture and on suitable differential hosts.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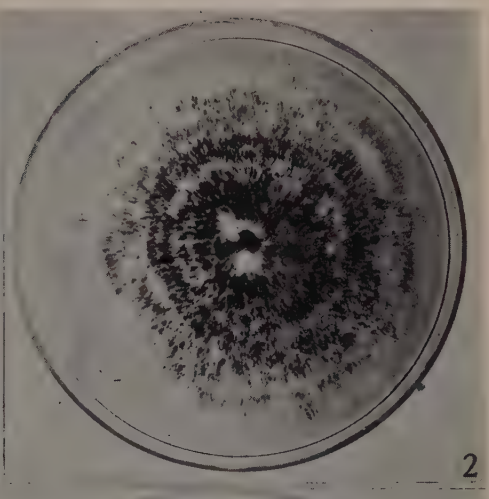
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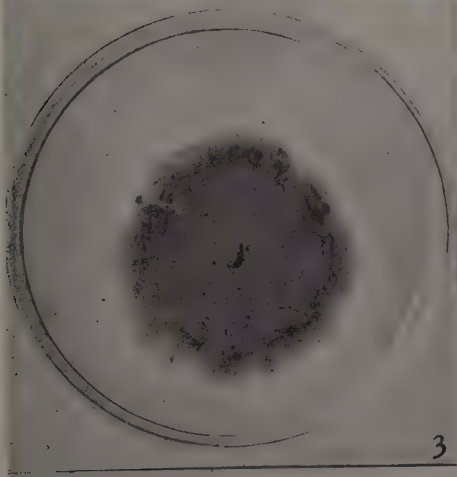
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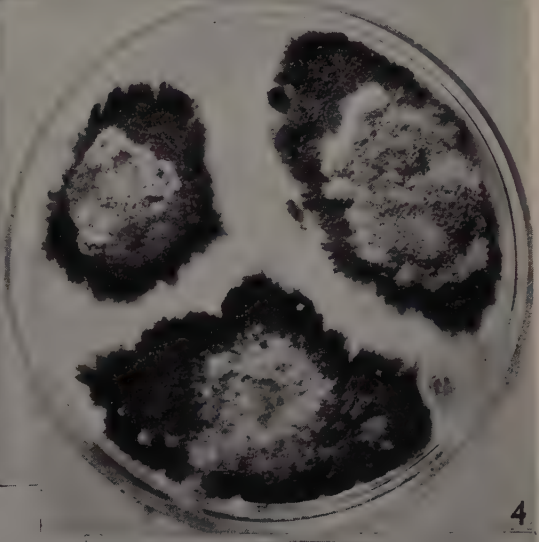
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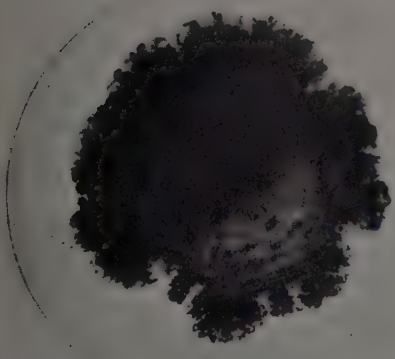
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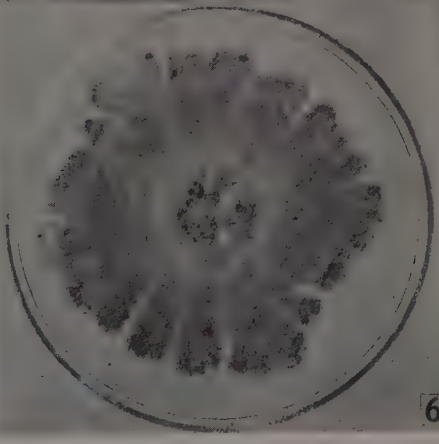
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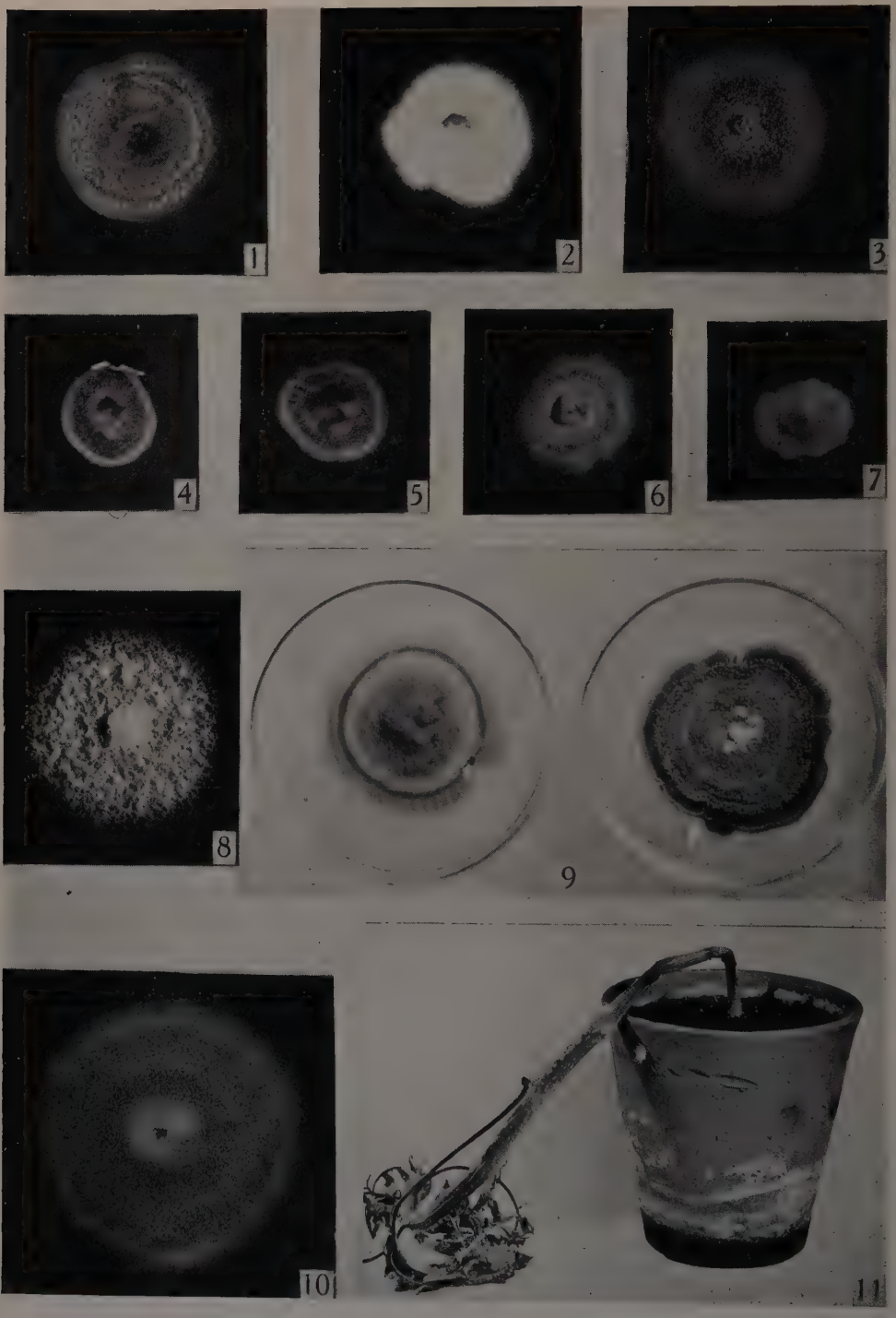
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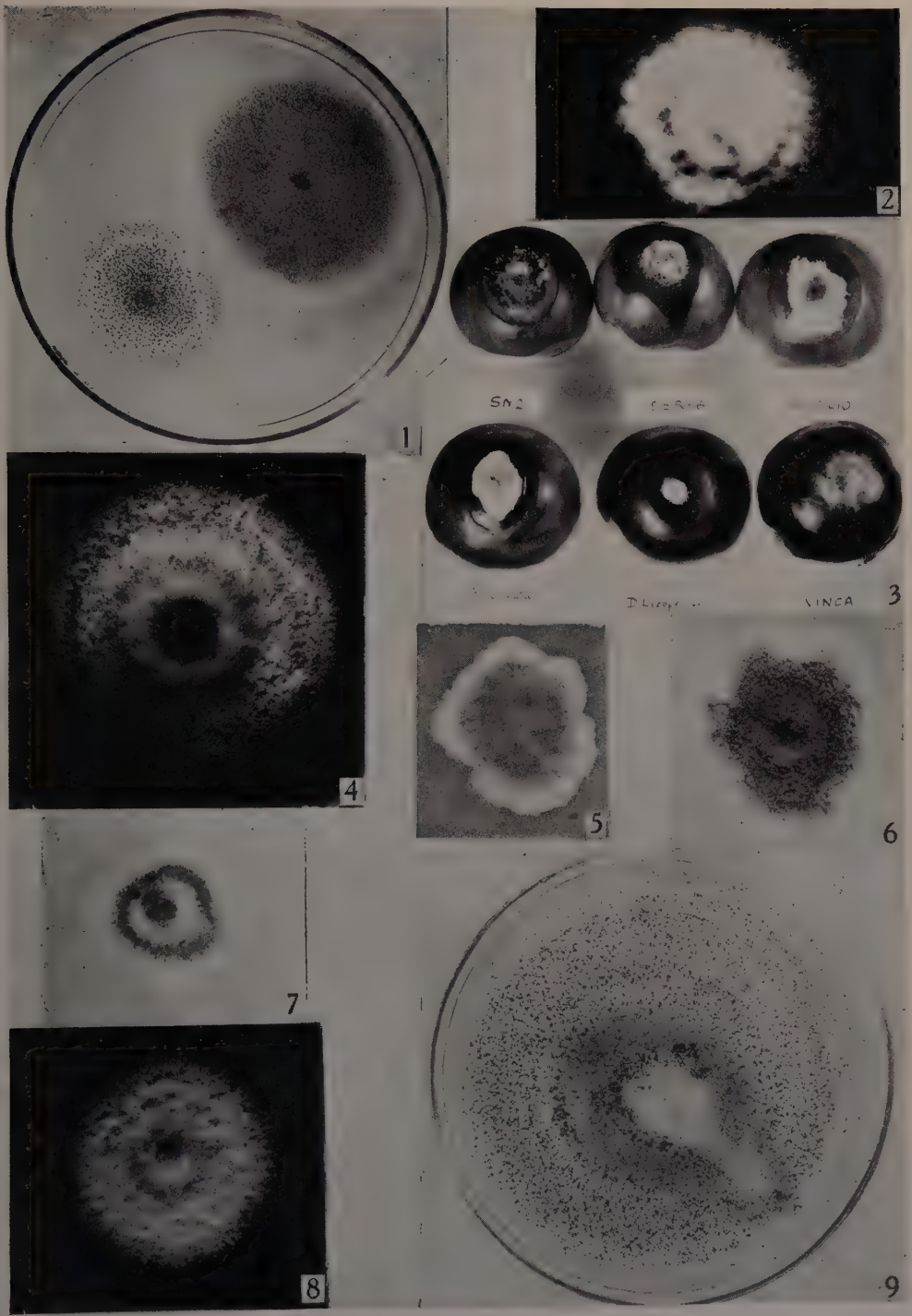
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EXPLANATION OF PLATES

All cultures photographed are on malt agar

Plate I

Fig. 1. Culture of strain 1, 6 days old.
Fig. 2. Lower surface of a 12 days old culture of strain 1 showing zoning.
Fig. 3. Culture of strain 31, 15 days old.
Fig. 4. Top left, strain 2; top right, strain 3; bottom, strain 4 after 16 days' growth on the same plate.
Fig. 5. Lower surface of a 12 days old culture of strain 2.
Fig. 6. Culture of strain 6, 9 days old.

Plate II

Fig. 1. Culture of strain 17, six days old.
Fig. 2. Culture of strain 19, 8 days old.
Fig. 3. Culture of strain 25, 8 days old.
Figs. 4–7. Cultures of strains 20, 21, 23 and 24 each 8 days old.
Fig. 8. Culture of strain 14, 8 days old.
Fig. 9. Cultures of strains 22 (left) and 23 (right), 1 month old.
Fig. 10. Culture of strain 26, 8 days old.
Fig. 11. Tomato plant killed by stem rot 6 weeks after inoculation with strain 7.

Plate III

Fig. 1. Strains 25 (left) and 27 (right) after 10 days' growth on the same plate.
Fig. 2. Strain 28, 8 days old.
Fig. 3. Tomato fruit rotted by strains 2, 3, 4, 1, 11 and 16, 13 days after inoculation.
Fig. 4. Strain 30, 8 days old.
Fig. 5. Strain 7, 8 days old.
Fig. 6. Strain 10, 14 days old.
Fig. 7. Strain 32, 14 days old.
Fig. 8. Strain 29, 8 days old.
Fig. 9. Strain 34, 14 days old.

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SPORE DISCHARGE IN *DALDINIA CONCENTRICA*

By C. T. INGOLD, *Birkbeck College, University of London*

(With 7 Text-figures)

Amongst angiosperms physiologists recognize a number of kinds of xerophyte. Two of the most outstanding are: (1) the succulent type (e.g. *Cactus* spp.) in which the plant body is, in the main, a reservoir of water, and (2) the drought-enduring type such as the creosote bush (*Covillea glutinosa*) in which growth ceases during the dry months and the small leaves pass the summer in a wilting condition reviving with the autumn rains (Maximov, 1929, p. 258).

Buller (1909 and 1922) has pointed out that the leathery and gelatinous lignicolous members of the Hymenomycetes are xerophytes of the drought-enduring type, and most lignicolous Pyrenomycetes are probably of the same physiological type. In most of the stromatal Pyrenomycetes growing on wood, spores are probably discharged from the perithecia only during wet periods when the fungal tissue is fully turgid. This has, for example, been clearly demonstrated for *Endothia parasitica*, the cause of American Chestnut Blight, and Anderson (1913) came to the conclusion that 'the ascospores are ejected into the air from the ostioles during rain and as long as the bark remains wet'. Heald and Studhalter (1915), studying the same fungus, found also that expulsion of ascospores occurs only during and immediately after rain when the stromata are fully moist, and that from March to October discharge occurs during each spell of rain. Since violent spore discharge in Pyrenomycetes involves the bursting of fully turgid cells (the asci) sufficient water must clearly be available for the perithecia if discharge is to continue.

Daldinia concentrica Ces. & de Not., whose large black perithecial stromata are such conspicuous objects on dead trunks and branches of ash, is also a xerophyte, but of a different type. It would seem to be a succulent xerophyte, the stromatal tissue representing a large water reserve, with the result that spore discharge can continue during long periods of drought. This paper is concerned mainly with the evidence for this statement.

Daldinia concentrica is probably the largest of the stromatal Pyrenomycetes of the British flora. The stroma is roughly hemispherical and often has a volume of 50 c.c. or more. The only British pyrenomycete in which the stroma is developed to a comparable degree is *Xylaria polymorpha*, and it will be interesting to see if that species resembles *Daldinia* in the physiology of its spore discharge.

In *Daldinia concentrica* the spores are normally discharged violently to a distance of 1·0–1·2 cm. If a detached stroma is placed on a piece of white paper in the still air under a glass cover, a deposit of sooty spores accumulates as a black band extending around the fungus to a uniform distance of 1·0–1·2 cm. Under certain conditions spores fail to be discharged violently

and escape instead in the form of spore tendrils as described by Bayliss Elliott (1920), but this method of spore liberation is uncommon under natural conditions.

In studying the daily march of spore discharge the arrangement shown in Fig. 1 was used. A glass slide supported on two wooden blocks was arranged over a detached stroma leaving a space of 1–2 mm. between the upper surface of the fungus and the lower surface of the slide. The fungus was freely exposed to dry laboratory air and there was no external water supply on which it could draw. Spores discharged from the upper, more or less flat, part of the stroma collected on the glass slide and the maintenance of the slide in that position prevented the upper surface of the stroma from becoming smothered by discharged spores. At approximately three-hourly intervals the rate of spore discharge was determined. For this a slide was used with a square centimetre, subdivided into square millimetres, etched upon it. This was substituted for the slide *S* (Fig. 1) and, by

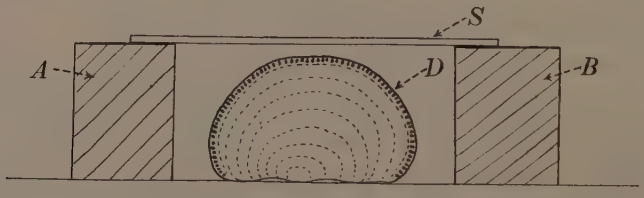

Fig. 1. Sectional view of arrangement for studying rate of spore discharge. *A* and *B*, wood blocks; *S*, glass slide; *D*, stroma of *Daldinia*.

fitting it to marks on the blocks *A* and *B*, the etched square was made to occupy, at each test, the same position relative to the fungus, thus ensuring that discharge from the same area of the stroma was sampled. It was found most convenient to expose the slide for fifteen seconds and after this exposure it was removed and the number of spores on the etched square counted under the microscope.

The results of this experiment are shown graphically in Fig. 2. It can be seen that discharge is essentially nocturnal and this has been confirmed in all the numerous specimens which have been kept under observation in the course of this work. In its nocturnal discharge *Daldinia concentrica* resembles *Hypoxylon fuscum* (Ingold, 1933).

The number of spores caught on a square centimetre of glass surface held just above the fungus gives roughly the spore output from the same area of the stroma. However, the particular stroma under observation had a perithecia-studded surface of 20 sq.cm. The maximum number of spores caught on 1 sq.cm. of the slide in fifteen seconds was 5400. For the whole stroma this gives an estimated rate of 432,000 spores per minute. It is interesting to note that this is of the same order of magnitude as the average output by a mushroom (*Psalliota campestris*). Buller (1909) found that the average rate of spore liberation from a fruit-body 8 cm. in diameter during the forty-eight hours of its spore-fall period was 670,000 per minute.

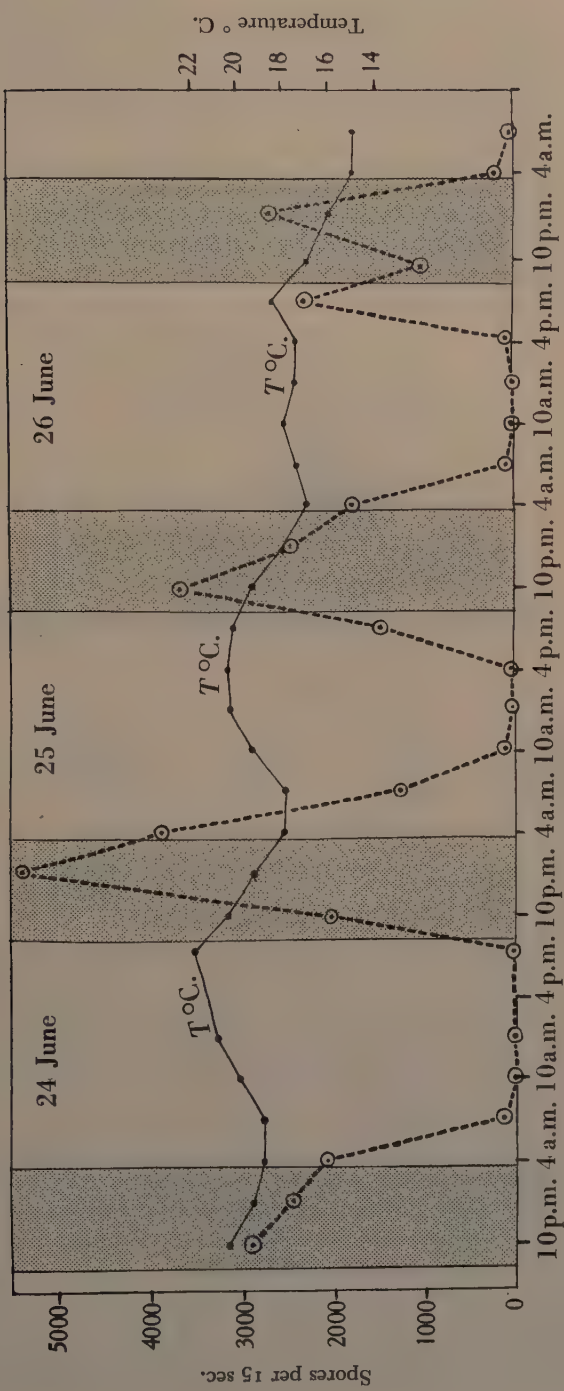

Fig. 2. Interrupted line: rate of spore discharge plotted against time. Continuous line: temperature. Periods from sunset to sunrise stippled.

It should be emphasized that the curve for spore-output plotted against time (Fig. 2) is based on few readings, since only eight observations were made each day out of a possible total of 5760 (i.e. the number of 15-second periods in a day). However, assuming the correctness of this graph and bearing in mind that the spores caught on the etched square represent only a twentieth of the total output of the stroma, an estimate can be made of the average daily spore production for the three 24-hour periods: 24–25 June, 25–26 June and 26–27 June. This works out at 133 million.

For the study of spore discharge from drying stromata the arrangement shown in Fig. 3 was used. A stroma was impaled on a blanket pin pushed

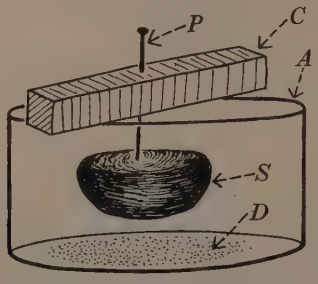

Fig. 3. Arrangement for collecting spore deposit. *S*, stroma; *P*, blanket pin; *C*, cork strip; *A*, crystallizing dish; *D*, spore deposit.

Table 1

	Original weight of stroma in g.	Original density	Period of spore discharge in days	Weight of stroma, when discharge ceased, in g.	Density when discharge ceased
A	4·83	—	20	1·35	—
B	26·02	0·96	27	6·10	0·25
C	34·48	1·01	33	6·92	0·21
D	24·69	1·02	26	6·84	0·31

through a strip of cork resting on the rim of a crystallizing dish, so that the discharged spores collected as a sooty deposit on the bottom of the dish.

In this series of experiments no quantitative determinations of spore output were made. Stromata of high density (approximately 1·0) were selected for study and each was exposed to dry laboratory air. It was noted daily if a visible spore deposit had formed overnight and the stroma was transferred to a clean crystallizing dish. In this way the spore discharge period for each specimen was determined, but it must be remembered that discharge may have been taking place for some time before the fungi were collected. During the course of the experiment each specimen was weighed at intervals. The results for four stromata are given in Table 1. Thus stroma *C* with an initial weight of 34·48 g. and a density of 1·01 continued to discharge spores for 33 days and only during the last ten days of this period was there any noticeable falling off in the density of the nightly spore deposit. When discharge ceased, the weight was reduced to 6·92 g. and the density to 0·21. During this period the change in volume was slight:

34 c.c. at the beginning, 32 c.c. at the end. The maintenance of the volume in spite of the considerable loss of weight is due largely to the rigid outer crust of the stroma.

The fact that spore discharge can take place for many days from a detached stroma has been recorded by Möller (1901), who, however, kept his specimens under a glass cover so that evaporation may have been slight. It must have been observed by many mycologists who have collected *Daldinia* and left stromata lying about in the laboratory. The surprising fact is that in dry air spore discharge can continue for so long.

In another series of experiments an attempt was made to give a quantitative estimate of the nightly output of spores during the drying of the stroma. The method used depends on the fact that if the spore deposit is suspended in a standard volume of water and if a definite depth of this suspension is interposed between a constant source of light and a photoelectric cell (Fig. 3), the suspension acts as a screen and the amount of light cut off due to the presence of the spores in the water depends on their concentration in the suspension.

Using a particular suspension, a series of dilutions was prepared (half-strength, quarter-strength and so on) and the amount of light absorbed by the original suspension and by each of the standard dilutions was determined, the zero value being given by water without any spores. From the data thus obtained a curve was constructed relating spore concentration, in arbitrary units, with the amount of light cut off by the suspended spores. This served as a calibration curve (Fig. 5).

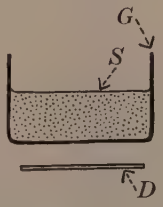

Fig. 4. Photoelectric method for measuring spore concentration. *L*, lamp; *G*, glass dish; *S*, spore suspension; *D*, sensitive disk of photoelectric cell.

In practice the nightly spore output was suspended uniformly in 50 c.c. of water and 20 c.c. of this suspension were poured into a glass vessel (*G* in Fig. 4) which was then placed immediately above the sensitive disk of a photoelectric cell. The reading given in foot-candles was subtracted from a reading obtained immediately before for which 20 c.c. of water were used in place of the suspension. From this value the spore concentration, in arbitrary units, was obtained from the calibration curve. For example, a particular suspension gave a reduction in light of 11·4 f.c. and this corresponded to a spore concentration of 5·4 *K*. *K* is a constant which can be estimated roughly. Using the same suspension twelve readings with a Thoma haemacytometer gave the spore-content of the suspension as 66·95 (S.E. 5·95) million. Equating this to the arbitrary value obtained by the photoelectric method gave a value for *K* of 12·4 (S.E. 1·1) million. Although the standard error (S.E.) is relatively high, this gives a clear picture of the order of magnitude of *K*.

The method of estimating spore concentration by using a photoelectric

cell is very sensitive and is also easy, a single determination occupying only a few minutes.

For the quantitative experiments the arrangement shown in Fig. 3 was placed in a desiccator containing anhydrous calcium chloride. In this way the air was kept not only dry but also still, so that practically all the discharged spores collected at the bottom of the crystallizing dish which was changed daily. Each nightly deposit of spores was suspended in water and the concentration determined by the photoelectric method. Two stromata were studied. Each had a density greater than 1·0 at the beginning of the experiment and each was weighed at intervals throughout. The results are recorded graphically in Fig. 6.

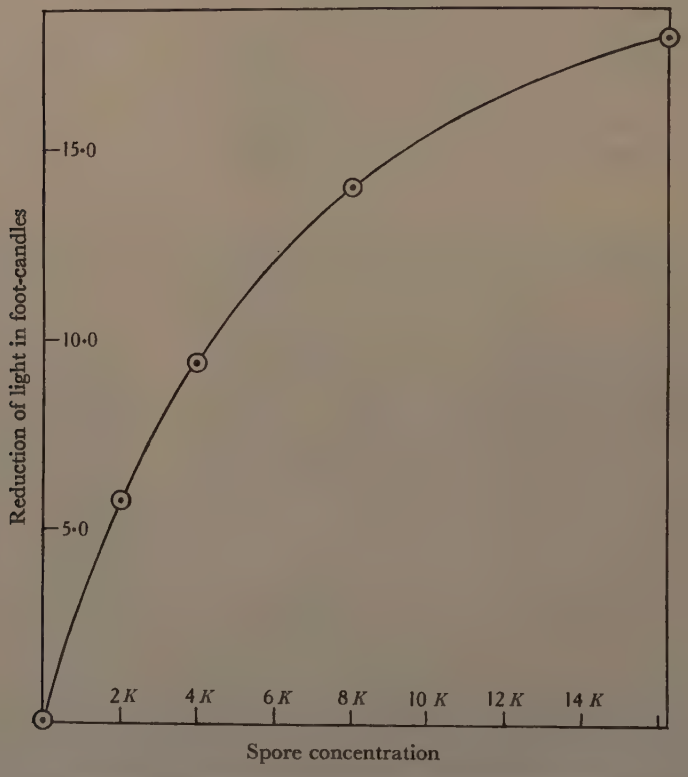

Fig. 5. Calibration curve relating reduction of light in foot-candles with spore concentration in arbitrary units.

It may be seen that for the first eleven days in the desiccator the rate of discharge showed no steady tendency to fall off. It fluctuated to some extent in both stromata probably due to variations in temperature, and it is interesting to note that during this period (1–11 June) the curves for the two stromata showed a clear parallelism with maxima on the three nights 2–3 June, 6–7 June and 10–11 June. After the first eleven days the rate of

discharge began to decrease steadily and finally, after 18 days for stroma *E* and 14 days for stroma *F*, discharge ceased. This final steady fall in spore output set in for *E* and *F* only when the weight of each had fallen to approximately one-half and discharge ceased when the weight was reduced to less than a third of the original.

The average daily spore output for the first eleven days in the desiccator was 155 million for *E*, and 69 million for *F*. These values compare very

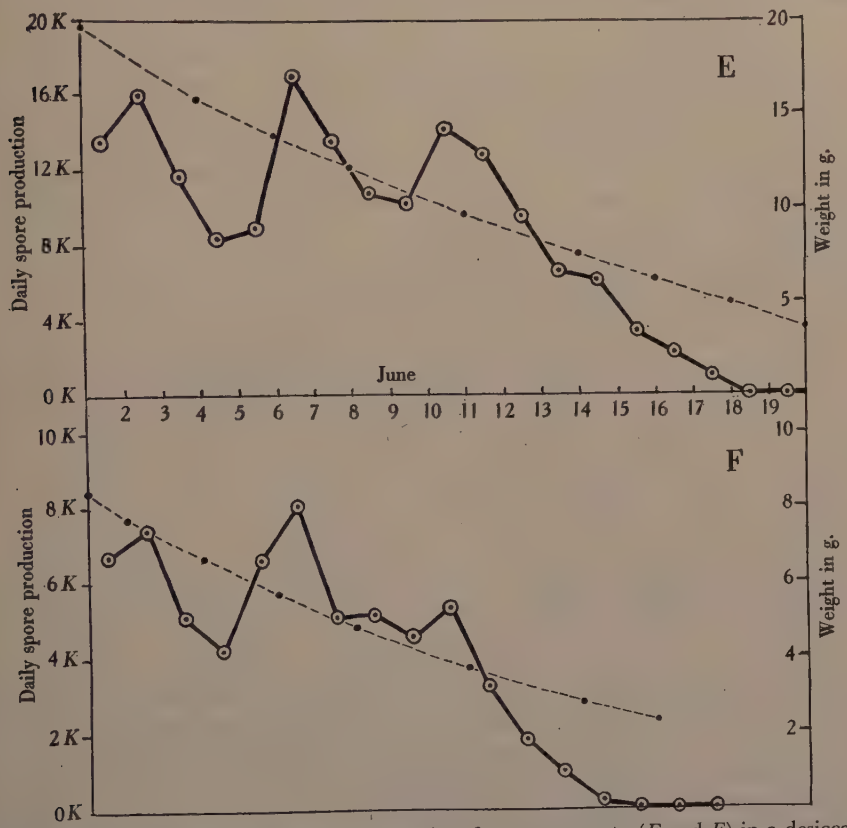

Fig. 6. Daily spore production plotted against time for two stromata (*E* and *F*) in a desiccator. Solid line shows daily spore production in arbitrary units. Interrupted line shows weight of stroma.

well with the figure of 133 million for the stroma used in the first experiment (see p. 44) which, however, had a volume about 50% greater than that of *E*.

It is interesting to calculate what part of the loss of weight of each stroma during the period of active spore discharge is represented by the weight of the spores themselves. Discharged spores were mounted in water and 100 were selected at random and measured. The average dimensions were $14{\cdot}2 \times 6{\cdot}8\,\mu$. Assuming that the spore is ellipsoidal with a density of 1·0, the weight of a million spores works out as 0·000344 g. The total spore output

of the stroma *E* during the experiment was 166·3 *K* which is approximately equivalent to 2062 million spores. The weight of these would be roughly 0·71 g. The loss of weight of the stroma during the period of active spore discharge was 15 g. Similarly, for stroma *F* the total spore output was 797 million corresponding to a weight of 0·27 g. and the loss of weight during the discharge period was 5·6 g. Thus the loss of weight is accounted for only to a small extent by the spores themselves and is probably mainly due to evaporation (transpiration), although some water is also lost as ascus sap discharged with the spores.

From the observations given above it is clear that *Daldinia concentrica* is a xerophyte capable of long-continued spore discharge under very dry conditions. It is suggested that this is possible because of the water reserve of the stromatal tissue, although this does not exclude the possibility that this tissue also contains a reserve of food. It may seem strange to suggest that this fungus is a succulent xerophyte. It does not feel succulent because of its hard outer crust, but if a stroma is examined during the early part of its discharge period, when its density is 1·0 or more, the stromatal tissue within the crust is found to be very juicy.

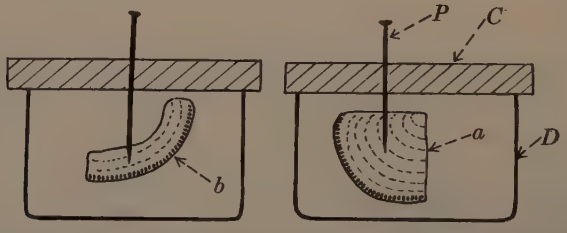

Fig. 7. Sectional view of arrangement used in studying spore output by half stromata. *a*, half stroma; *b*, half stroma with some stromatal tissue removed; *P*, blanket pin; *C*, narrow cork strip *not* covering the dish *D*.

If the stromatal tissue behaves as a reserve, discharge of spores should cease earlier if part of this tissue is removed. To test this two similar experiments were carried out. In both experiments a fairly large and more or less hemispherical stroma was selected and cut into two half-hemispheres. One of these (*a*) was left without further treatment. The other (*b*) had part of its stromatal tissue scooped out, but a broad zone of this tissue was left below the perithecia to ensure, as far as possible, that they received no injury as a result of the treatment. All the cut surfaces in (*a*) and (*b*) were vaselined. The arrangement of the experiment is shown in sectional view in Fig. 7. It should be noted that the cork strip *C* did not cover the dish, so that the stromata were freely exposed to the dry laboratory air. The crystallizing dishes were changed daily and in both experiments the duration of spore discharge for the two halves (*a*) and (*b*) was determined. The results are shown in Table 2. In experiment *H* the weights of the two halves were originally: (*a*) 22·51 g. and (*b*) 23·09 g. and then from (*b*) 8·32 g. of stromatal tissue were removed.

Although it is unsafe to argue from experiments involving the mutilation of an organism, the results of these two experiments are, nevertheless, con-

sistent with the view that the stromatal tissue is a reserve, since with part of it removed spore discharge comes earlier to an end.

Within an active perithecium there does not appear to be any air, the asci and paraphyses being surrounded by a rather viscous fluid. When an active stroma is cut across, the liquid contents of the perithecia can easily be seen with a lens. It is only after spore discharge has ceased that a gas phase makes its appearance within the perithecia and, when this has happened, it does not seem possible to revive their activity even by placing the stroma with its base in water.

Table 2

	Duration of spore discharge in days	
	Half stroma (*a*)	Half stroma (*b*)
G	18	12
H	26	13

Summary

The ascospores of *Daldinia concentrica* are normally discharged to a horizontal distance of 1·0–1·2 cm. Discharge is essentially nocturnal.

Spore discharge may continue from isolated stromata exposed to dry laboratory air for 20–30 days and during this time the density of the stroma decreases from about 1·0 to 0·2–0·3.

A method, involving the use of a photoelectric cell, is described for the rapid estimation of the nightly spore output in arbitrary units. Using this method, the nightly spore production of stromata enclosed in a desiccator was studied, and it was found that for the first eleven days spore output showed no tendency to decrease, although the density of the stromata fell from about 1·0 to about 0·5.

Experiments are described in which part of the stromatal tissue was removed and in consequence the period of spore discharge was considerably reduced.

It is suggested that *D. concentrica* is a xerophyte of the succulent type capable, by virtue of the water reserve in the stroma, of long-continued spore discharge under extremely dry conditions.

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ECOLOGY OF THE LARGER FUNGI

By JOHN GRAINGER, *Department of Plant Pathology, West of Scotland Agricultural College, Auchincruive, by Ayr*

(With 6 Text-figures)

The British Mycological Society is founded upon a great tradition of field work. My home county of Yorkshire has inherited a long line of fungus forays, one of which provided the initial conference of this more famous daughter Society. Field work has laid the foundations of systematic mycology, which is still advancing. The present generation, however, not finding such a basic necessity for naming and classification, could begin the field investigation of ecology. Plant pathology, or applied mycological ecology, must always begin as a field study. It is invariably the better for outdoor inspiration.

Fungi are among the most prolific of living organisms. *Lycoperdon giganteum* probably holds the record, with a production of about 7,000,000,000,000 spores per fructification, and other species have very large numbers. Most of these spores die, but what is the mechanism of establishment of the infinitesimally small number which are successful? They must, among other factors, find a medium of suitable moisture content, with nutrient matter adjusted qualitatively and quantitatively to their needs, and of suitable relative acidity (*p*H). It is possible to measure some of the necessary conditions by the field methods of ecological survey. Of the three factors mentioned above, relative acidity is most easily measured in the field; estimations can be made on different substrates—soil, dung, and even wood and bark.

The effect of *p*H of the substrate

Methods

Measurement of *p*H of the soil can be carried out conveniently in the field by colorimetric methods. Most soils are within the range of British Drug Houses Soil Indicator (*p*H 4·0–8·0). Several permanent standards are available, but the most portable is the chart of printed colours prepared for the B.D.H. barium sulphate soil testing outfit. This, used with the ordinary soil testing kit, will give a reading with most soils and humus layers. Tests have been made of soil scraped from the bases of fructifications—perhaps the best arbitrary place for preliminary observations. Results are recorded on sheets 5 × 3 in., with all relevant data, and are filed as a card index. The very convenient refinement of specially printed sheets (Fig. 1) has been provided for the present investigations by Mr R. Fowler Jones, who has always helped Yorkshire mycologists in many ways.

Terrestrial species

Over 1400 estimations have now been made, and show certain possibilities of correlation. It had been expected that species would show a certain relation with *p*H of the substrate (Figs. 3 and 4 and Table 1), but it also appears that whole genera may favour certain sections of the *p*H scale (Figs. 2, 3). Clearly defined generic preferences for a particular limited range of acidity, such as are shown by *Russula*, *Lactarius* and *Coprinus*, seem to reinforce the soundness of these systematic groupings, apart from other considerations. Wide toleration of relative acidity, as in the genus *Hygrophorus* might be taken as an indication of a group still undergoing change.

Name ..... *Date* .....

Loc. .....

Associated Plants .....

Coll. ..... *Det.* ..... *Kind of Spore* .....

Host ..... *Alt. Host.* .....

.....

.....

Soil	*p*H	% Water	% Org. Matter				

Fig. 1. Sheet for recording ecological data. The headings 'Kind of Spore', 'Host' and 'Alt. Host' are used for studies on the ecology of Rusts and other fungi not considered in this paper.

Table 1 shows the *p*H range favoured by several of the more common species for which most records are available. Most species have a preference for moderately acid conditions, though a minority favour neutral or slightly alkaline reaction.

James Bolton, in his volume *History of Fungusses growing about Halifax* (1788), mentions *Morchella esculenta* as growing round that town. It cannot be found there now and, with increasing industrial development of the district, a considerable 'limestone' flora of higher plants has also disappeared (Grainger, 1942). The present investigation shows that *Morchella* requires soil of *p*H 7·0–8·0. It would seem that the ground, once sufficiently alkaline in parts for the growth of *Morchella* and several lime-loving plants, has gradually become more acid, and this has eliminated the calcicolous species.

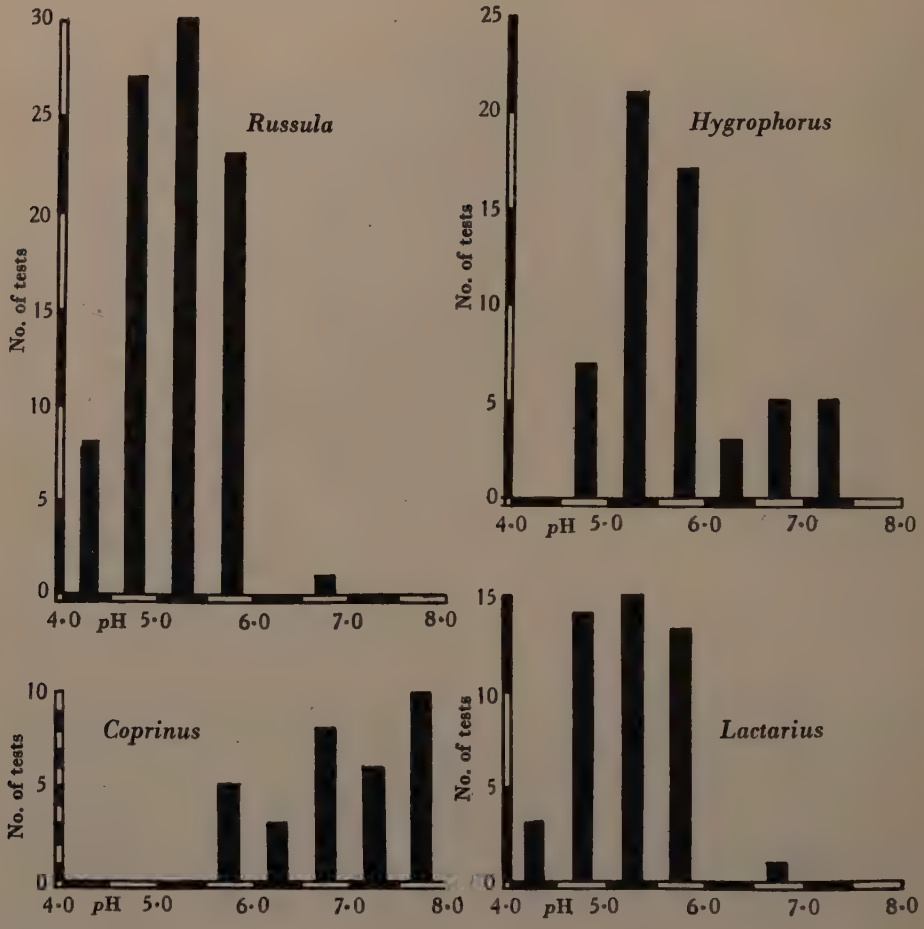

Fig. 2. *p*H requirements of fungal genera. The estimations include the following numbers for each species:

Russula, 88 determinations: *adusta* 2, *atropurpurea* 17, *cutefracta* 1, *cyanoxantha* 14, *elephantina* 1, *emetica* 13, *fragilis* 1, *graminicola* 1, *lactea* 2, *luteotacta* 1, *nigricans* 10, *ochroleuca* 19, *olivacea* 1, *Velenovskyii* 4, *venosa* 1.

Hygrophorus, 57 determinations: *calyptraeformis* 5, *ceraceus* 5, *chlorophanus* 10, *coccineus* 5, *conicus* 7, *eburneus* 1, *metapodius* 2, *miniatus* 1, *nigrescens* 1, *niveus* 1, *pratensis* 6, *psittacinus* 8, *puniceus* 2, *subradiatus* 1, *virgineus* 2.

Coprinus, 32 determinations: *atramentarius* 3, *comatus* 4, *lagopus* 2, *micaceus* 17, *niveus* 1, *papillatus* 1, *plicatilis* 3, *radiatus* 1.

Lactarius, 46 determinations: *camphoratus* 1, *ichoratus* 2, *piperatus* 2, *pyrogalus* 4, *quietus* 3, *rufus* 3, *subdulcis* 16, *subumbonatus* 6, *subtomentosus* 1, *torminosus* 1, *turpis* 7.

The common mushroom, *Psalliota campestris*, is found more often on substrata between *p*H 6·5 and 7·5, and has not yet been observed below *p*H 5·8 (Fig. 4). This fact should have significance for mushroom growers, for the erratic behaviour of this fungus in cultivation must owe a good deal to inappropriate reaction of the manure and casing soil. One bed which failed to produce mushrooms was partly distributed over a border prepared

Table 1. *p*H *ranges of some common fungi*

	*p*H range	No. of determinations
Amanita rubescens	4·0–5·8	21
Amanitopsis fulva	4·5–5·8	10
Anellaria separata	5·8–8·0	16
Boletus chrysenteron	4·7–6·7	11
B. edulis	4·5–6·0	14
Collybia maculata	3·5–5·5	13
Coprinus micaceus	5·8–8·0	17
Hygrophorus chlorophanus	5·0–7·4	10
Hypholoma fasciculare	4·0–6·8	17
Laccaria laccata	4·8–6·3	25
Lactarius subdulcis	4·0–5·8	16
Lycoperdon pyriforme	5·7–6·7	12
Morchella esculenta	7·0–8·0	7
Panaeolus phalaenarum	5·7–7·2	15
Paxillus involutus	4·0–5·8	27
Phallus impudicus	3·5–7·0	18
Psilocybe semilanceata	5·0–6·8	16
Russula atropurpurea	4·0–5·8	17
R. cyanoxantha	4·2–5·9	14
R. emetica	4·8–6·0	13
R. nigricans	5·2–6·0	10
R. ochroleuca	4·0–5·8	19
Scleroderma aurantium	4·0–5·8	17
Stropharia semiglobata	4·0–6·0	55

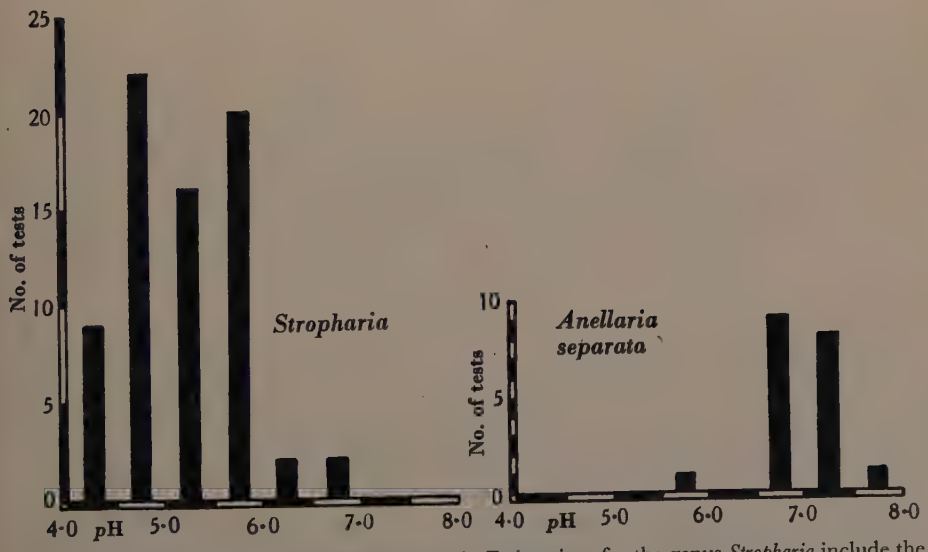

Fig. 3. *p*H requirements of coprophilous fungi. Estimations for the genus *Stropharia* include the following number for each species: *semiglobata* 56, *merdaria* 8, *stercoraria* 7.

for tomatoes, on which the fungi then appeared. Investigation showed that the original manure was *p*H 4·8 and the casing soil *p*H 5·0, showing that conditions were too acid for the mushroom. The tomato compost, from which the mushrooms grew, was *p*H 6·0, i.e. within the tolerance of *Psalliota campestris*. Many growers add lime and gypsum to their mushroom composts, and this should always be done, in order to attain a *p*H of 6·5–7·0.

Coprophilous species

Fungi which grow on dung also show marked preference for particular ranges of relative acidity. *Stropharia semiglobata* favours more acid dung, whilst *Anellaria separata* tends towards alkaline conditions (Fig. 3). The fullest test of this idea was to find both species on the same piece of dung, but each fungus was growing in its appointed sphere of *p*H: it was the dung which varied. Variation could result from the kind of food given to the voiding animal, and the length of time after voiding. Alkaline specimens are usually those more freshly deposited.

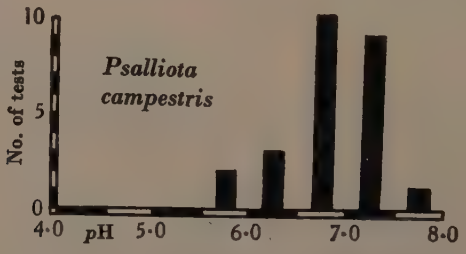

Fig. 4. *p*H requirements of *Psalliota campestris*.

Humaria granulata is often the first species to appear on alkaline cow manure, and *Anellaria separata* may follow. *Stropharia semiglobata* and *S. stercoraria* are not particularly prevalent until the later stages of decay, when the dung patch is becoming somewhat broken and decrepit. There is thus an ecological indication that dung, though it may be voided at varying *p*H, nevertheless undergoes a progressive change towards greater acidity as it lies upon the surface. Leaching by rain may also play a part in this change.

Lignicolous species

It is not easy to determine the relative acidity of wood. Colorimetric estimations with thymol-blue and cresol-red indicators would place it about *p*H 2·9, but this may not represent the effective reaction of the whole tissue. It seems fairly certain, however, that fungi which grow upon fresh or living wood, have chosen one of the most acid substrates in nature. Fallen logs, as they decay, however, undergo a progressive change of *p*H towards neutrality. There is also a change in texture or 'hardness' which can be measured by estimating the pressure required to drive a metal point into the wood, up to one or more arbitrary marks. An apparatus similar to that shown in Fig. 5 was used for this purpose. Fresh soft woods require a

pressure of 30–40 lb., and hardwoods a pressure of 40–50 lb. for the point to penetrate to the second line. When the wood is rotten, the point will penetrate to the full depth with only 3 or 4 lb. pressure. The instrument reinforces *p*H measurements in assigning intermediate points of decay, though their readings are not by any means parallel. *Xylaria hypoxylon*, for example, seems to favour wood which is approaching neutrality (*p*H 7·0) but which still retains about 80 % of the hardness of the fresh substrate. *Fomes annosus*, on the other hand, appears to be able to grow on wood which retains only 20–25 % of its original hardness, but is still fairly acid—*p*H 5·0. It would seem that two different types of decay are represented by these examples. Succession of fungi upon fallen logs doubtless owes much to the

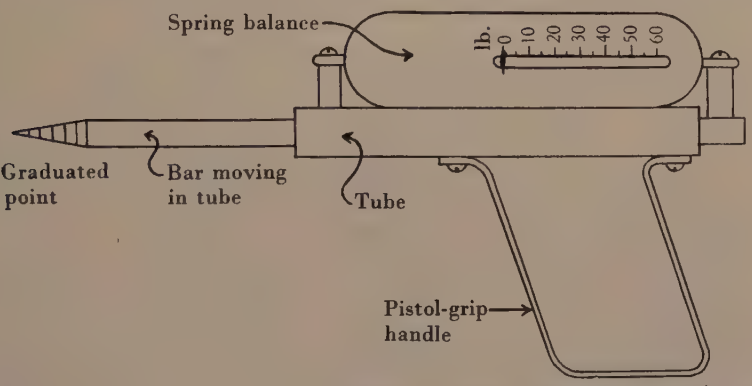

Fig. 5. Diagram of an apparatus for measuring 'hardness' or stage of decay in wood.

stage of decay presented to successive depositions of spores, but the fungi also contribute to the decay. *Trametes mollis* reduced the hardness of wood to about 27 % of its initial value, and *Volvaria volvacea* grew on wood which had a hardness 25–32 % of that on which the fungus was not growing. There are many difficulties in this work, and Table 2 is included, but tentatively, to show potentialities of this line of ecological approach.

Table 2. *Ecology of succession of fungi upon fallen logs*

	*p*H	'Hardness' of habitat (lb.)	'Hardness' of healthy wood (lb.)	% reduction in 'hardness'
Stereum rugosum	4·3	12–16	30–40	60
Pluteus cervinus	5·5	15	42	64
Fomes annosus	5·0	9	45	80
Xylaria hypoxylon	7·0	32	40	20

Bark is throughout much more nearly neutral than wood. Colorimetric readings have varied between *p*H 6·0 and 7·3, but here again these values may not represent the reaction of the whole tissue. The ecologist must be careful to distinguish between actual growth of a fungus on the bark, and mere fructification thereon. *Stereum purpureum*, for example, can certainly grow on wood, but fructifies on the bark, whereas *Nectria cinnabarina* can probably draw the greater part of its nutrition from the bark.

Requirements of water and organic matter

Methods

It is necessary to weigh in the field samples of soil or loam destined for moisture determinations. This usually needs shelter for the hand balance which is used. Material can be filled into a tared crucible, reweighed, and then carefully wrapped in paper bearing a note of both weights, and other data for the sample. This can then be dried and incinerated as soon as convenient.

Table 3 suggests that, for growth and reproduction of the larger terrestrial basidiomycetes, water-holding capacity of the substratum is probably of

Table 3. *Requirements of water and organic matter*

	Average water content % of fresh wt.	Average organic content % of fresh wt.	No. of determinations
Amanita rubescens	38·5	12·4	11
Galera hypnorum	53·5	15·6	5
Hygrophorus chlorophanus	42·9	11·5	5
Laccaria laccata	40·2	14·4	13
Lactarius pyrogalus	27·6	6·9	4
L. subdulcis	56·6	21·2	5
Lycoperdon pyriforme	41·6	10·1	5
Paxillus involutus	46·5	24·2	15
Phallus impudicus	56·6	25·3	5
Psilocybe semilanceata	46·6	14·7	5
P. coprophila	61·7	22·5	4
Russula atropurpurea	46·9	24·3	7
R. cyanoxantha	39·6	15·7	7
R. emetica	59·3	26·7	10
R. ochroleuca	47·5	22·6	11
Scleroderma aurantium	46·1	15·6	7
Stropharia semiglobata	63·6	23·7	18

more importance than the amount of organic matter *per se*. The average water contents in the table are those of the habitat, but several determinations suggest that they are usually close to the water-holding capacities of the composts at the time fungal fructifications appear. Perhaps the most significant fact is that the water contents are very much higher than those of arable land, where moisture determinations over 30 % are rare. This would account for the disappearance of the larger fungi when grassland is ploughed; the surface layer of organic matter, which is mainly responsible for holding the larger quantities of water, is broken and dispersed in the soil. Some basidiomycetes can, however, grow and fructify on the new conditions; *Lactarius pyrogalus* of Table 3 would probably succeed, and at Meltham, *Russula nigricans* was the sole species which survived the ploughing of an old pasture with a rich and varied fungus flora, as detailed below. The low amount of organic matter required by *Lactarius pyrogalus*, and the high water contents associated with the two coprophilous species *Stropharia semiglobata* and *Psilocybe coprophila* are other noticeable features of Table 3.

Changes in the fungus flora

Do fungi appear in the same station in successive years? Are there annual and perennial mycelial masses? How far is the fungal flora of a given area liable to change from year to year? To what extent is the fungus flora dependent upon the ecology of higher plants? These questions, which animated James Bolton in 1788 (see also Grainger, 1940), cannot yet be answered very fully. A certain amount of field work, however, can provide suggestions and indicate the relative importance of the ecological factors mentioned in previous sections.

Habitat and succession

Two half-acre plots have been kept under detailed observation by Miss J. Grainger for the last four years, every fungal fructification being counted at approximately weekly intervals. By great good fortune, both habitats were changed during the counts.

The plot at Reservoir field, Meltham Mills, near Huddersfield, was a

Table 4. *Total number of sporophores, Reservoir field—old pasture*

	Average *p*H 5·0			Average *p*H 6·0
	1942	1943	1944	1945
Amanita rubescens	66	32	50	—
*Boletus badius**	12	6	15	—
*B. edulis**	13	—	—	—
B. erythropus	5	5	—	—
B. subtomentosus	—	1	17	—
*Collybia butyracea**	—	1	23	—
Hygrophorus laetus	—	29	123	—
Russula xerampelina	13	1	3	—
R. fellea	32	6	42	—
*R. emetica**	2	14	21	—
*R. nigricans**	1	9	—	3

↑ Ploughed, limed and reseeded

* Species whose tolerance of *p*H 6·0 has been established by previous survey.

very old pasture, running back almost to rough moorland, and dominated by *Aira flexuosa*. It was ploughed in the spring of 1945, limed and reseeded.

Table 4 shows that the fungus flora varied considerably in the three years before ploughing, but after that disturbance the change was drastic. *Russula nigricans* was the sole survivor. Liming raised the *p*H of the ploughed soil from an average of 5·0 to an average of 6·0. Five species shown by an asterisk (*) in Table 4, are known, from the *p*H survey discussed earlier in this paper, to be able to grow and fructify at *p*H 6·0. *Amanita rubescens* could still be found on an unploughed headland of the old pasture, to which lime had been added (*p*H 5·8). It does not seem that change in soil reaction alone could account for the drastic change following ploughing, liming and reseeding. Change of water-holding capacity by ploughing has already been discussed, and this is deemed to be the major factor. In support of this idea, the moisture-holding capacities of ploughed and

unploughed soil, both of which had been limed, were found to be 58·5 and 31·4 % respectively. From Table 3, it would seem that the ploughed soil could not hold sufficient water for the growth of most fungi; *Russula nigricans* is an exception, which has frequently been found on very dry situations.

The second plot was in Banks Wood, close to the first. It was a mixed oak and beech wood, with ground vegetation of *Holcus* and *Aira*. It was felled in the winter 1942–3.

Table 5 shows that *Boletus chrysenteron* disappeared with the trees; the other three species diminished more slowly. There was no significant change in *p*H, and in 1945, it was *p*H 4·5–5·0, within the limits already established for the four species of Table 5. *Amanitopsis vaginata* and *Boletus chrysenteron* often grow right away from woods, so it is unlikely that disappearance of the trees removed any element directly essential for their

Table 5. *Total number of sporophores, Banks Wood (mixed oak)*

	1942	1943	1944
Amanitopsis vaginata	36	16	—
Boletus chrysenteron	100	—	—
Russula adusta	33	1	—
Scleroderma aurantium	15	14	4

↑ Wood felled

immediate nutrition. The removal of trees would, however, probably disturb the water relations of the soil below, for evaporation would be greater after the trees had gone. Lack of sufficient water would seem to be the important factor in this case also.

Annual and perennial mycelium

Fairy rings of the terrestrial species *Entoloma porphyrophaeum* and *Lactarius turpis* appeared in fields at Meltham in 1943, but not a vestige of either could be found in 1944 or 1945. Several hundred fructifications of *Armillaria mellea* arose from the ground away from trees in 1943. The species had not fructified there for three years previously, nor did it appear in 1944 and 1945. Changing frequency of humicolous species from year to year would doubtless reflect the great element of chance involved in spore distribution. It would also seem to fit the assumption that their mycelial masses are usually annual. On the other hand, the lignicolous species *Stereum karstenii* Bres. has only been found in Yorkshire at Buckden, in 1922, when it was the first British record, and again in 1936. *Panus torulosus* fruited on the same log, and at the same place on the log, two years in succession at Cawthorne in 1941 and 1942. *Polyporus betulinus* can fruit on the same birch tree for at least two successive years. Continuity of the individual in lignicolous species over more than one year would seem to indicate a possibility of perennial mycelium. The well-known annual layers of *Fomes annosus* provide further direct evidence of perennial growth.

Periodicity and climate

The concentration of fructification of the agarics into an autumn maximum raises an interesting question in ecology. *Psalliota campestris*, when provided horticulturally with suitable climate and nutrition, will grow and fructify at any time of the year. The larger basidiomycetes, when grown in artificial

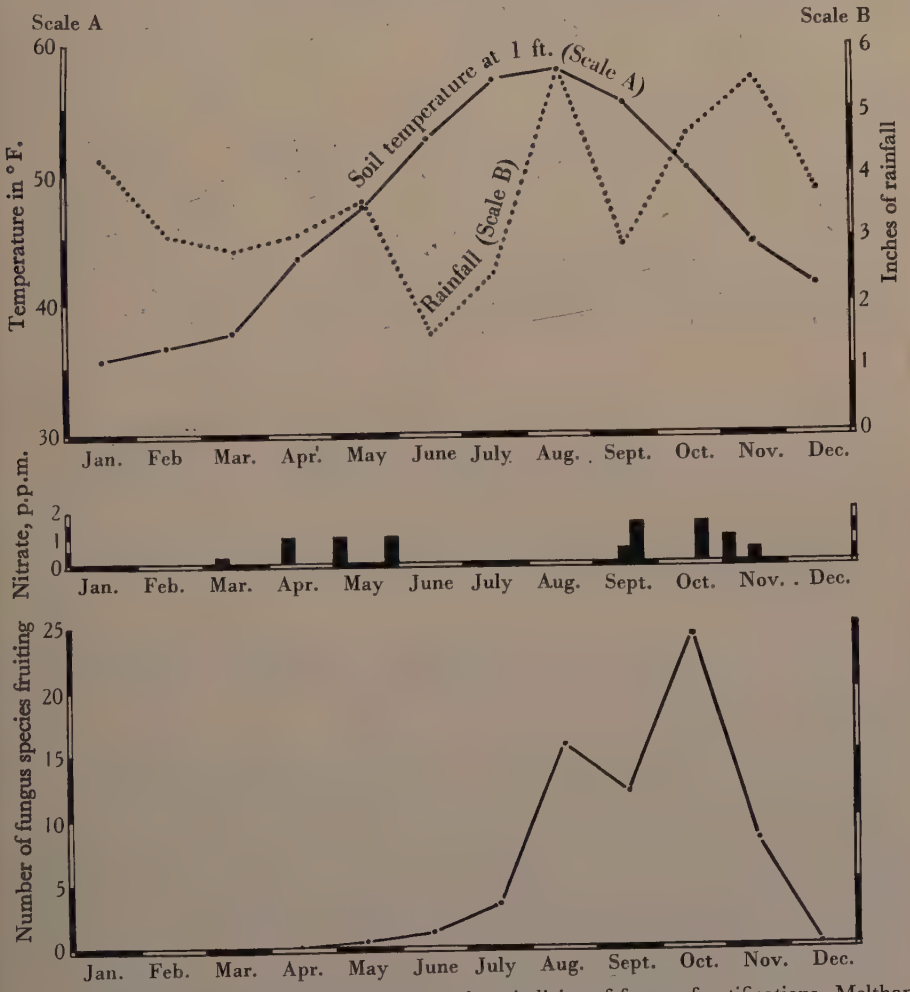
Scale A
Scale B
Temperature in °F.
Inches of rainfall
Soil temperature at 1 ft. (Scale A)
Rainfall (Scale B)
Jan. Feb Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
Nitrate, p.p.m.
Number of fungus species fruiting

Fig. 6. Meteorological data, nitrate values and periodicity of fungus fructifications, Meltham Mills, Huddersfield; averages for 1941, 1942 and 1944.

culture, can fruit in any month. Natural conditions impose an autumn maximum, for which environmental factors might account. Mrs Mary Grainger (1942) has suggested that autumn is the only time when there are, simultaneously, a sufficiently high soil temperature, with enough rainfall for high soil moisture, and adequate supplies of available nitrogen. Spring

provides available nitrogen and soil moisture, but has low soil temperature. Summer brings a high enough soil temperature, but soil water is low and spare nitrogen is at a minimum. Winter has little nitrogen, low soil temperature, and perhaps more than adequate soil moisture. Such is the working hypothesis.

Weekly records of fungal fructifications made over four years in one locality by Miss Jennie Grainger, have been combined with meteorological data obtained by Mr A. Broadbent at a station about one mile distant. Nitrate measurements were also made on water draining from the site, using the presumptive method of Thresh, Beale and Suckling (1933). This was taken as a rough indication of nitrogen level in the soil. The collective results are shown in Fig. 6 and support the hypothesis. Each factor has *some* effect. Low rainfall in September, for example, is correlated with fewer species of fungi in fruit. No single factor, or combination of two factors, however, is adequate to explain the observed fungal periodicity. Maximum fructification in October is correlated with the only month when nitrogen was abundant, soil temperature over 50°, and rainfall over four inches. All other months fall short of this triple desideratum.

Summary

Species of the larger fungi have definable preferences for particular ranges of *p*H of the substrate. The majority favour acid conditions but a minority prefer alkaline reaction.

Some genera also appear to have similar definable preferences.

The ecology of coprophilous species depends very largely upon reaction of the medium.

Most humicolous basidiomycetes require a high average water content in the substrate. Studies of two ecological changes suggest that this factor is of major importance.

The autumnal maximum of fungal fructification reflects the only time of year when soil temperature, soil water, and the level of available nitrogen, are simultaneously sufficient.

Ecology of the lignicolous fungi can be investigated in the field by correlated measurements of *p*H and 'hardness' in order to determine the particular type and stage of decay. Rotting wood generally undergoes a change from very acid to neutral reaction; bark provides approximately neutral conditions throughout.

This survey is designed to be provocative rather than finite. It is the result of using simple field methods, but indicates many possibilities of ecological investigation. It has had all the social value of a foray, being a co-operative work with Miss Jennie Grainger, Mrs Mary Grainger, Mr A. Broadbent, Mr C. Ridgwick, and members of the Mycological Committee of the Yorkshire Naturalists' Union. Mr A. A. Pearson kindly helped with the determination of several species.

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UROMYCES GENISTAE-TINCTORIAE (PERS.) WINT. IN SCOTLAND

By J. A. MACDONALD, *Department of Botany, University of St Andrews*

In September 1934, I found sori containing uredospores of *Uromyces Genistae-tinctoriae* on the leaves of *Genista anglica* near Inverness (Wilson, 1934). The *Genista* grows among heather at the side of Loch Duntelchaig about 700 ft. above sea-level. The rust was collected in the same locality yearly till 1941. Uredospores only have been found. The sori appear to be confined to the leaves, and are mostly hypophyllous. Leaves of the current season bear sori from June to October.

A large number of seeds was collected from infected plants in 1935. Plants raised from them in St Andrews all remained healthy.

Genista anglica and *Sarcothamnus* (*Cytisus*) *scoparius* are the only species included in the Sydows' (1904) list of host plants for *Uromyces Genistae-tinctoriae*, which occur at Loch Duntelchaig. The hosts listed include other species of *Genista* and several species of *Cytisus* and *Laburnum*. *Cytisus scoparius* and *Ulex europaeus* are both quite common near the loch. They have been examined frequently for signs of infection but with negative results.

Dr Malcolm Wilson has very kindly shown me his draft notes on *Uromyces Genistae-tinctoriae*, collected for his projected revision of Grove's (1913) *British Rust Fungi*. From these it is clear that the presence of the aecidial stage of this rust in Britain has not been satisfactorily established. The aecidium has been recorded on the continent on *Euphorbia Cyparissias* by Dietel (1919) and Kobel (1921), and on *E. virgata* by Treboux (1912). The former species is British and Druce (1932) gives its range from South Devon to Westerness. The nearest parts of this latter vice-county are over twenty miles distant from Loch Duntelchaig, and far inside its borders stretch mountain and moorland. It is therefore safe to assume that, in this area, *Uromyces Genistae-tinctoriae* lives as a repeating rust.

In September 1936, numerous plants of *Cytisus scoparius* and *Ulex europaeus* were examined on the banks of the Caledonian Canal at Inverness. One or two plants of *Cytisus scoparius* had their leaves infected with the uredospores of a rust. Microscopic examination showed that the spores were similar in appearance to those occurring on *Genista anglica*. The following measurements show that the spores on *Cytisus* tended to be more nearly equal in length and breadth and that the largest of them were slightly longer and markedly broader than the largest measured from *Genista*.

Genista anglica uredospores from leaves: 21·1–28·8 × 18·6–22·5 μ; average 24·6 × 20·7 μ.

Cytisus scoparius uredospores from leaves: brown-walled, 3–4 germ pores; 20·9–29·3 × 18·9–28·1 μ; average 23·9 × 22·1 μ.

Only a very few teleutospores were observed. They were almost round, with a well-marked apical germ pore.

Both types of spore agree with Kobel's (1921) description of spores from this host.

Each year one or two bushes of *C. scoparius* are found infected, at the same spot. Uredospores are present from June to January. All leaves appear to be free from infection for the rest of the year, but a few branch infections do occur so that the plants are never entirely clear of the rust.

In December 1936, one or two uredosori were found on the spines of *Ulex europaeus* growing intermixed with one of the infected *Cytisus scoparius* plants. No other infected *Ulex europaeus* has been found so far. The spores differed considerably in appearance from those occurring on *Cytisus scoparius* or *Genista anglica* as the following measurements show.

Ulex europaeus uredospores from spines: 21·7–38·4 × 18·3–21·9μ; average 28·6 × 20·3μ.

Cytisus Laburnum three hundred yards distant is not infected.

The solitary infection on *Ulex europaeus* is very interesting. The natural assumption is that spores from *Cytisus scoparius* brought it about and that the rust on *C. scoparius* has not adapted itself properly to the new host. The experience of continental workers has been that any particular group of aecidiospores from *Euphorbia* is not able to infect by any means all the recorded hosts for the uredospore and teleutospore stages, e.g. Guyot (1937) infected *Cytisus Laburnum* with aecidiospores from *Euphorbia Cyparissias* but was unable to infect *Cytisus scoparius* from the same source. The inability of uredospores formed on one leguminous host to infect another has also been recorded. Both these facts indicate the presence of specialized races within the species. Kobel (1921) divides the species into three forms which differ slightly from each other in teleutospore characters. The hosts for form A are *Cytisus* spp. including *C. Laburnum*, and *Genista* spp. B is also found on *Cytisus Laburnum* and on *Caragana* spp. C is recorded on *Caragana arborescens* only. The position of the rust on *Cytisus scoparius* is regarded as doubtful.

Infection experiments were undertaken in an attempt to discover the relationship existing among the rust populations occurring near Inverness.

(1) In August 1938, leaves from *Genista anglica* and *Cytisus scoparius*, bearing uredosori, were brought to St Andrews. They were placed separately on wire gauze trays suspended inside bell-jars. One plant of *Genista anglica* was then placed under each jar for a period of forty-eight hours. Conditions were kept moist by lining the jars with damp blotting paper and sealing the foot with moist cotton-wool. Plants of *Cytisus scoparius*, *Ulex europaeus*, *Cytisus Laburnum* and *Genista tinctoria* were then treated in the same way. Great care was taken to keep the two lots of infective material separate at all times. The two sets of plants were stored in cold frames about two hundred and fifty yards apart. All plants were examined at regular intervals for a month. Of those exposed to infection from *Genista* uredospores, only *G. anglica* became infected. Uredospores from *Cytisus scoparius* infected that plant only. Infection was heavy on *Genista* and rather lighter

than under natural conditions on *Cytisus*. Sori formed on both leaf surfaces. All infected leaves were removed in both experiments. Ten days later a second crop of spores appeared on the leaves of *Genista anglica*. No more were formed on *Cytisus scoparius*. There were no stem infections on any of the plants. While no sori formed on *Ulex europaeus* as a result of exposure to spores from *Genista* or *Cytisus* the plants exposed to spores from the latter did develop brown spots on both leaf and stem spines. The brown, dead tissue contained hyphae quite similar to those of the rust in living leaf tissues of *C. scoparius*, but it was not possible to identify these hyphae.

These experiments were repeated in 1939, 1940 and 1941 with similar results.

(2) Seed of *Euphorbia Cyparissias*, the alternative host occurring in Britain, was obtained in the spring of 1940. In the summer of the same year two of the plants raised from this seed were placed in pots beside plants of *Genista anglica* which were infected. Two others were placed with infected plants of *Cytisus scoparius* at the same time. No infection of the *Euphorbia* occurred that season or during 1941. In addition, during the spring of 1941 two euphorbias were planted out under infected *Cytisus scoparius* bushes at Inverness and two were planted among infected *Genista anglica* at Loch Duntelchaig. These four euphorbias were not attacked by the rust.

When an opportunity occurs again I intend to repeat my attempts to infect *Euphorbia Cyparissias*. If this can be done there is always the possibility that the distinct forms of *Uromyces Genistae-tinctoriae* which appear to exist on *Genista anglica*, *Cytisus scoparius* and *Ulex europaeus* may be induced to change their hosts. Additional species too may become infected. The inability of the rust to attack *Euphorbia Cyparissias* in the experiments so far undertaken is to be expected because no teleutospores have been found on *Genista anglica* and very few on *Cytisus scoparius*. Teleutospores are obviously not necessary for the survival of the rust. The fact that it repeats on *Genista* and *Cytisus* shows that the uredospores are able to survive the fairly severe conditions which they sometimes experience.

Uromyces Genistae-tinctoriae as it occurs in the Inverness area is made up of biologically distinct populations on *Genista anglica* and *Cytisus scoparius*. There are slight morphological differences between the uredospores. A third population is almost certainly established on *Ulex europaeus*. Uredospores differ markedly from those occurring on the other two hosts. As only one infection has been found it has not been possible to try to infect *Genista* or *Cytisus* from *Ulex*. Mutation leading to pathogenicity has been recorded by Newton and Johnson (1940) in *Puccinia graminis Tritici*. It seems likely that by this means the rust on *Cytisus scoparius* has come to produce uredospores capable of infecting *Ulex europaeus* and that this colonization is still going on at the present time.

When experiments on these rust populations are more complete it may be found advisable to distinguish three species. In the meantime it seems safe to say that there are both biological and morphological differences in the rust material occurring on the three different hosts. The three populations may be tentatively distinguished from each other as forms within the

species *Uromyces Genistae-tinctoriae* (Pers.) Wint. The following nomenclature is proposed:

✓*Uromyces Genistae-tinctoriae* (Pers.) Wint. f. *anglicae* f.n. Forma specialis ex *Genista anglica*; uredosporis rotundatis vel ellipticis, 21·1–28·8 × 18·6–22·5 μ.

✓*Uromyces Genistae-tinctoriae* (Pers.) Wint. f. *scoparii* f.n. Forma specialis ex *Cytisus scoparius*; uredosporis rotundatis vel ovatis, 20·9–29·3 × 18·9–28·1 μ.

✓*Uromyces Genistae-tinctoriae* (Pers.) Wint. f. *Ulicis* f.n. Forma specialis ex *Ulex europaeus*; uredosporis ellipticis vel oblongis, 21·7–38·4 × 18·3–21·9 μ.

This work was interrupted in 1941 but is now being resumed.

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NOTE

CHYTRIDIUM LECYTHII (INGOLD) N.COMB.

By E. K. GOLDIE SMITH, *Royal Holloway College*

(With 1 Text-figure)

In March 1943, when working in Dr C. T. Ingold's laboratory at University College, Leicester, I had the opportunity of studying living material of *Rhizophydium Lecythii* Ingold, parasitizing the rhizopod *Lecythium hyalinum*, from the same locality in which the fungus was originally found. The chytrid was described by Ingold (1941), but he failed to observe the discharge of the zoospores. However, in the living material at my disposal I was able to establish that dehiscence of the sporangium is by a lid which may either hinge backwards (Fig. 1, *E–J*) or become completely detached (Fig. 1, *A*) and that the zoospore has a single posterior flagellum.

Since dehiscence is by a lid, it is necessary to transfer this species from the inoperculate genus *Rhizophydium* to the operculate genus *Chytridium*, and the name becomes, therefore, *Chytridium Lecythii* (Ingold) n.comb.

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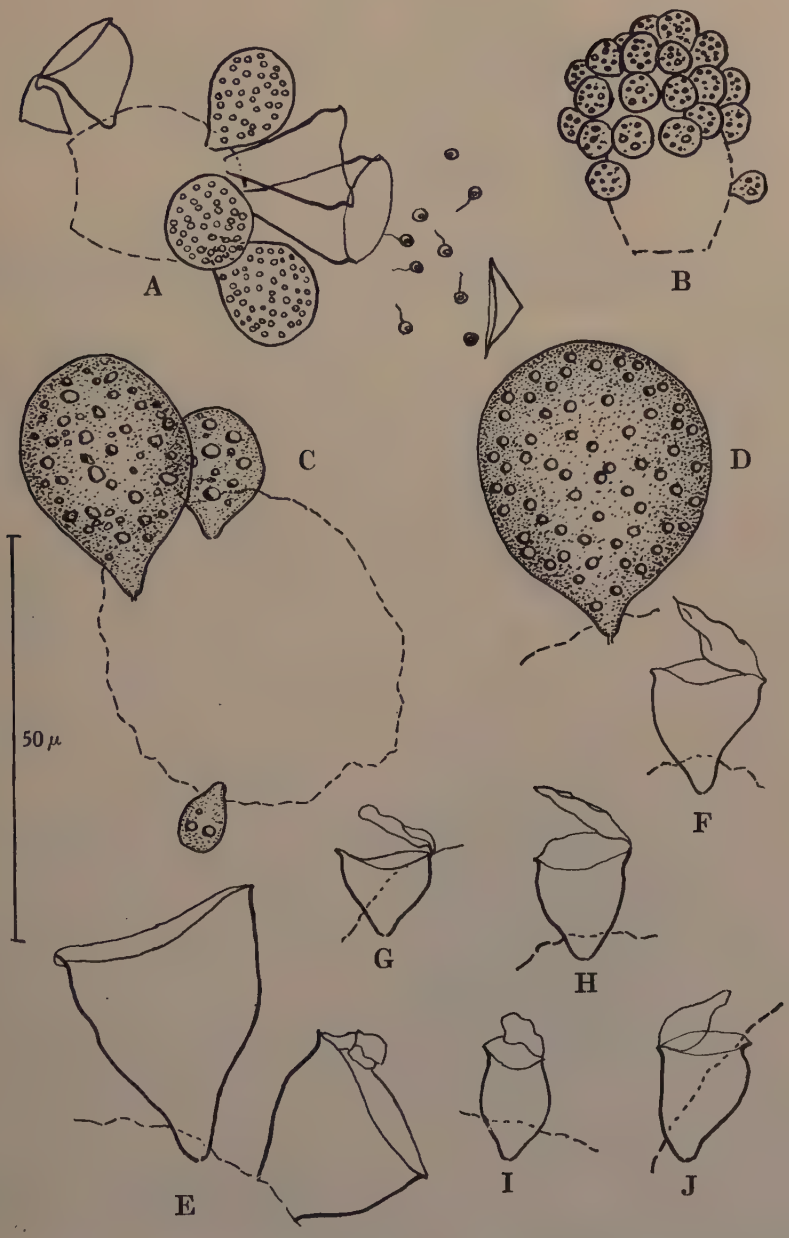

Fig. 1. *Chytridium Lecythii* on *Lecythium hyalinum*. *A*, *B*, Freehand sketches; *C–J*, camera lucida drawings. The surface of the rhizopod is indicated by a dotted line.

AN UNDESCRIBED SPECIES OF *CHAETOMIUM*, WITH FOUR-SPORED ASCI

By S. J. HUGHES

(With 1 Text-figure)

In November 1944, an unfamiliar *Chaetomium* arose as contaminant of an agar plate during an attempt to isolate a fungus parasitizing a wireworm; in pure culture the *Chaetomium* fruited abundantly on rabbit-dung agar with straw.

Through the kindness of the Director of Kew, and Miss E. M. Wakefield, material of all but four of the twenty-eight species of *Chaetomium* described by Chivers (1915) in his monograph have been examined. As far as I am aware, eight species of *Chaetomium* have been described as new just prior to or since 1915. These are: *C. fiscicolum* Petrak (1915), *C. subterraneum* Swift and Povah (Swift, 1929), *C. tortuosum* Garbowski (1936), *C. ochraceum* Tschudy (1937), *C. cancroideum* Tschudy (1937), *C. dolichotrichum* Ames, *C. microcephalum* Ames and *C. pachypodioides* Ames. Tschudy (1937) examined a culture of the type isolation of *C. subterraneum* Swift & Povah and found it identical with *C. globosum* Kunze.

Dr L. M. Ames very kindly sent me, on request, cultures of his own three species and also the two species erected by Tschudy in 1937.

In 1849 Fries described *Chaetomium hispidum* as follows: 'In *Ch. hispido* (gregario, atro, peritheciis hemisphaericis subnitidis, fibris sparsis rigidis divergentibus, in eodem caule jove pluvio monstrabat nucleum fluxilem, sporasque absque ascorum vestigio; sequente die sicco et sereno praebuit ascos amplos, clavatos, pellucidos, sporis 4 seriatis ovatis simplicibus lutescentibus. Interdum deficit perithecium; gelatina floccis inspersa.'

Of this description Chivers states that 'No measurement of structures are given and it is impossible to arrive at a satisfactory conclusion regarding his material. The fact that the asci are four-spored would, in any case, exclude this species from *Chaetomium*.'

The *Chaetomium* described below differs from *C. hispidum* Fries in that it does not possess 'fibris sparsis rigidis divergentibus', 'ascos...clavatos' or 'sporis...ovatis...lutescentibus'. Singular characters of the terminal hairs weighed against the possibility of this fungus being a variety of one already described, assuming of course that, if a four-spored variety had arisen, the hairs would remain the same.

As the fungus differs markedly from the specimens of species examined and the descriptions of others it is proposed as new with the following diagnosis:

Chaetomium tetrasporum n.sp.

Perithecia grey, subglobose, ostiolate, 300–450 μ in diameter, on a poorly differentiated tuft of rhizoids. Lateral hairs numerous, of two sorts:

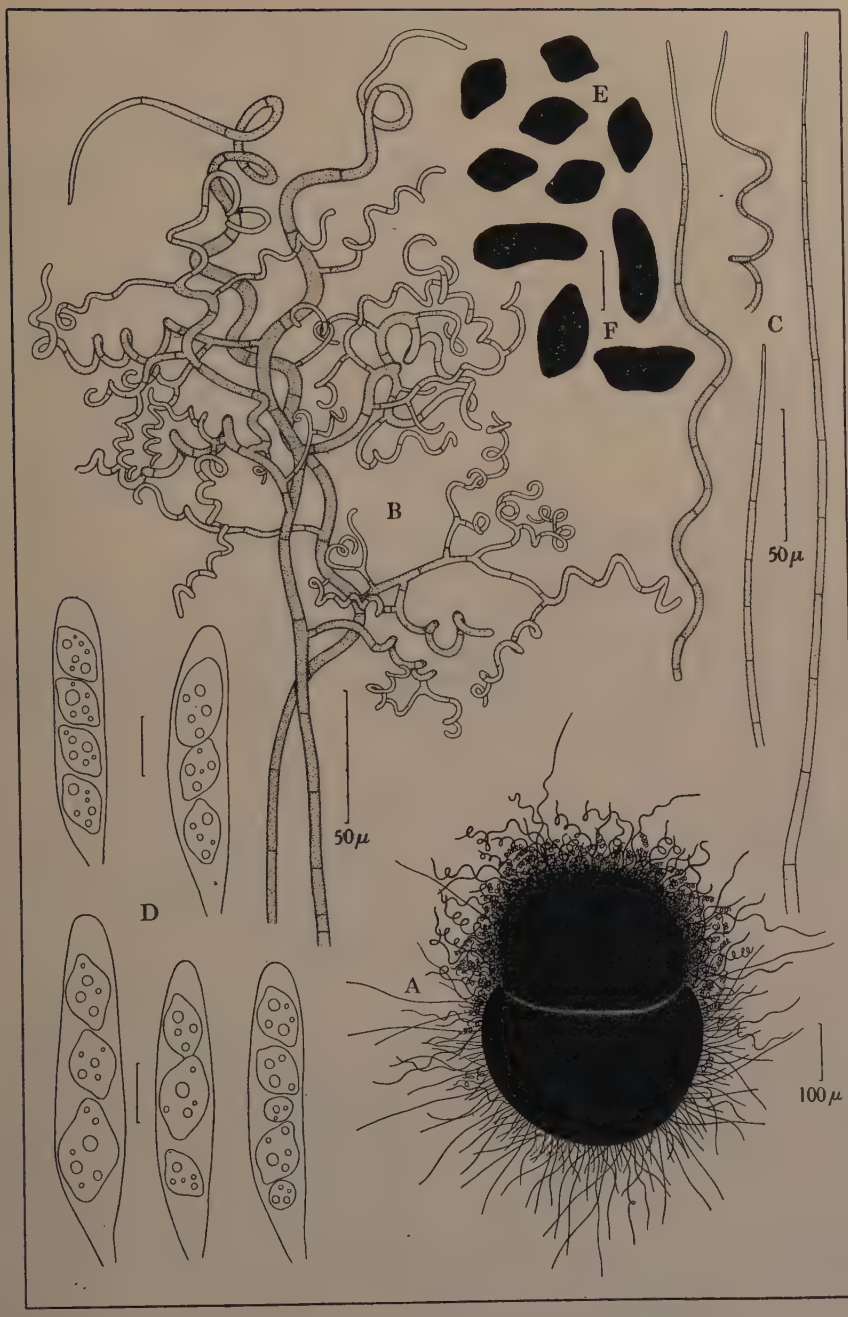

Fig. 1. *Chaetomium tetrasporum*. *A*, mature perithecium; *B*, two much branched terminal hairs; *C*, straight and coiled lateral hairs; *D*, asci showing young ascospores with oil globules. Asci producing two normal spores with one giant spore, and three normal spores with two dwarf spores are also figured; *E*, normal ascospores; *F*, giant ascospores.

Except where otherwise indicated, each scale is 10 μ long.

(*a*) straight, unbranched, finely roughened, septate, 3·5 μ wide, pale olive-yellow to brown at base, tapering to hyaline apex; (*b*) loosely coiled, olive-brown at base, slightly paler at apex, usually unbranched but sometimes with a short, coiled lateral at its base, heavily roughened with minute warts, septate, up to 5 μ wide; terminal hairs septate, loosely coiled, dark olive-brown and roughened but paler and smoother towards the rounded apex, about 5 μ wide, bearing conspicuously branched, loosely coiled laterals, whose ultimate branches are narrower, closely and evenly coiled with up to eight convolutions, each coil pale olive-brown or hyaline and almost smooth, with a rounded apex. Asci more or less cylindrical, stalked, 65–83 × 7·5–10·5 μ, pars sp. 45–52 μ long, four-spored. Ascospores obliquely uniseriate, at first hyaline, later dark olive, lemon-shaped and strongly apiculate, often angular, elliptical and compressed when viewed edgewise, 10·5–14 × 6–9 μ, mostly 12 × 7 μ. Paraphyses absent.

Chaetomium tetrasporum Hughes, sp.nov.

Perithecia grisea, subglobosa, ostiolata, 300–450 μ diametro, in rhizoidibus male evolutis insidentia. Pili laterales copiosi, nunc recti, haud ramosi, septati, 3·5 μ diam., sparse asperati, basi ex olivaceo-luteo brunneim sursum hyalini, nunc laxe spiraliter convoluti, basi olivaceo-fusci, 5 μ diam., sursum pallidiores, vix ramosi, verrucis minutis dense asperulati. Pili terminales septati, ramosi, basi 5 μ diametro, fortiter asperulati, olivaceo-fusci, sursum pallidiores, ramulis extremis hyalinis; rami majores laxe spiraliter convoluti, ramuli extremi angustati, 3·5 μ diam., arcte aequaliterque ad 8 spiraliter contorti, dilute olivaceo-brunnei vel hyalini, apicibus fere laevibus. Asci cylindraceo-clavati, basim versus attenuati, 65–83 × 7·5–10·5 μ, pars sporifera 45–52 μ tetraspori, aparaphysati. Sporae oblique monostichae, olivaceo-fuscae, limoniformes, utrinque fortiter umbonatae, saepe tetragonae, 10·5–14 × 6–9 μ (av. 12 × 7 μ).

Hab. in culturis fimi cuniculorum, et stramenti in laboratorio Cardiff, Cambriae. Nov. 1944.

Chaetomium tetrasporum is a very distinctive species and, apart from its four-spored asci, it can be recognized readily by the great number of small coils comprising the head. The development of the hairs can be observed in young perithecia quite easily as the ascospores take a long time to exude through the ostiole and obscure the view. Indeed, the ascospores are slower developing in this species than in any others kept under observation; this may well be due to the reduced number of spores developing in each ascus. As in many pyrenomycetes with four-spored asci, interesting abnormalities of spore production are seen; giant and dwarf spores are quite common but cultures from single spores have not been made to determine whether '+' and '−' strains exist.

Terminal hairs from six perithecia have been examined and all show coiling in a counter-clockwise manner (see Davidson & Gregory, 1937).

Dried type isolations have been deposited in the herbaria of the Imperial Mycological Institute, Royal Botanic Gardens at Kew, British Museum

(Nat. Hist.), U.S. Department of Agriculture at Washington, the Central Experimental Farm, Ottawa, and Farlow Herbarium, Harvard University, Cambridge, Mass.

I am indebted to Miss E. M. Wakefield for editing the Latin diagnosis, to Dr S. P. Wiltshire of the Imperial Mycological Institute for providing laboratory facilities and to Dr L. M. Ames for sending the cultures mentioned in the text.

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MYRIANGIUM

By T. PETCH

In 1924 I published an account of the genus *Myriangium*, giving its history and describing the known entomogenous species, after examination of specimens in the herbaria of London and Paris. In 1940 J. H. Miller published a paper, 'The Genus *Myriangium* in North America', which I have only recently (1945) been able to consult.

In his historical review (p. 589), Miller wrote, 'In the United States, Tuckerman in *Genera Lichenum* in 1872 shows that *Myriangium Duriaei* of Europe is equal to *Myriangium Curtisii* of America'. I assume that 'is equal to' means 'is the same as'. But Tuckerman scarcely did that. He certainly suggested that they were 'by no means satisfactorily distinguished' from one another, but he did not treat them as the same. He stated (in error) that both species occurred in Europe, having misinterpreted Nylander and Millardet, but as regards the United States his paragraph on *M. Duriaei* records that 'reaching Cuba, [it] should be likely to appear also within our southern boundaries. And the plant (*M. Curtisii* Mont. & Berk.) which does occur here, and extends northward along the coast (Carolina, Curtis, Ravenel; Alabama, T. M. Peters; Massachusetts, C. F. Sprague, H. Willey),' etc. Thus Tuckerman in 1872 was not aware that *M. Duriaei* occurred in North America; for him all North American specimens of *Myriangium* were then *M. Curtisii*.

After the publication of *M. Curtisii* in 1849, North American specimens of *Myriangium* were assigned indiscriminately to that species, e.g. by Ravenel. Then it was found that some of these specimens were *M. Duriaei*, and hence it was concluded that *M. Curtisii* was merely a large *M. Duriaei*. That idea has been revived by Miller.

In his general account of the genus (p. 590) Miller wrote: 'Petch observed some globose spores in several species of *Myriangium*, but the writer has found only oblong-elliptical ones in parts of the same specimens he examined. The spherical shape appears only in cross sections of spores as shown by the figures of the writer.' I find I gave details of three specimens in which I found globose spores. One of these specimens, Ellis 1279 in Herb. Kew., was not examined by Miller, according to his list, but he examined parts of the same Ellis number in other herbaria, and assigned them to *M. asterinosporum* (Ell. & Everh.) Miller. As, however, he found much larger ascospores than either Ellis and Everhart or myself, and did not find any globose spores, there would appear to be a possibility that Ellis 1279 was a mixture (see p. 76). I did not make use of microtome sections when measuring the asci and ascospores, using them only to determine the arrangement of the asci. To avoid further misconceptions, I may say that the sections shown on Pl. III of my paper were stained.

Figs. 1–4, Pl. II, of my paper are of *M. Duriaei* as it occurs in England. Fig. 6 of the same plate is from a Curtis specimen of *M. Curtisii*, and the

section shown on Pl. III, fig. 4, is from the same specimen. Miller referred the latter to *M. Duriaei*, stating that the section was a typically expanded *M. Duriaei*. I have never seen any herbarium specimen of *M. Duriaei* to match that. It certainly seems strange that although the distribution of *M. Duriaei* extends through temperate and tropical zones, this 'expanded' form occurs only in the United States. Miller recorded that the 'English specimen from Currey on *Fraxinus* is the best developed one of the foreign collections in the New York Botanical Garden herbarium', and elsewhere he listed it as 'Currey, W., *M. Duriaei*, on *Fraxinus excelsior*, April 1876'. It would have been interesting to have had information about the apothecia of that specimen. Should not the name of the donor be W. Curnow?

Under *M. asterinosporum* (Ell. & Everh.) Miller, the latter author wrote: 'This species was designated *M. Curtisii* by the writer (l.c.) in 1938, and also by Petch (l.c.) in part, but recent investigations lead to the conclusion that Montagne had both of the common American species before him and combined the two in his description of *M. Curtisii*.' Miller referred (in part) to my account of the specimens which were under *M. Curtisii* in the Montagne herbarium in 1921, but before proceeding to discuss those again, it may be as well to interpolate a note regarding old-established herbaria which may enable the reader to understand the position.

Specimens acquired by a herbarium are placed in their appropriate place on sheets or in covers (folders) according to some recognized classification. Those which come in unnamed are identified by the staff, but specimens sent in named, or purchased as exsiccata, are usually 'laid in' as named by the seller or sender, as there is rarely time for the staff to verify the identifications and they cannot be specialists in every branch of systematic mycology. Consequently, any given folder may contain more than one species, and the situation is only remedied when some one examines the contents of a folder and sorts out and names the different species.

The type of *M. Curtisii* was collected by Curtis, was sent to Montagne by Berkeley, and was described by Montagne in 1849. The type specimen should be in Montagne's herbarium, and it should be a specimen collected by Curtis during or before 1849. Anything collected after that date or by some other collector cannot be the type.

In the Montagne herbarium in 1921 there were six specimens marked *Myriangium Curtisii*. I number them here for convenience of reference. No. 1 is named '*Myriangium Curtisii* Berk. & Mont.' by Broome. No. 2 appears to be part of the same gathering, and is marked '*Myriangium Curtisii* Berk. & Mont., Car. Inf.' by Berkeley, and '*ex* clar. Berkeley, 1853' by Roussel. No. 3 is an American specimen from Sprague. No. 4 is Lindig 2583, Nova Granata. All the foregoing are *M. Duriaei*, and they are all specimens named by other mycologists than Montagne and subsequent to 1849. No. 5 is marked by Montagne '*Myriangium Curtisii* Mont. & Berk., Car. Inf.', and is enclosed in a piece of paper bearing the inscription '*Myriangium*, the best specimen' by Curtis. No. 6, '1442 Car. Inf.' is marked by Montagne '*Myriangium Berkeleyi* Montag., *Myriangium Curtisii* Berk. & Mont. Car. Super. [*sic*] cl. Berkeley', and matches no. 5.

No. 5 should be taken as the type. It answers to Montagne's description. Note that Curtis was not able to name it except generically, a fact which may indicate that it had not been named when he sent it. Absolute certainty is impossible, as it is not dated, and Montagne did not give any date or collection number in his description.

I see no reason to suppose that Montagne drew up the description of *M. Curtisii* in 1849 from two species. The fact that he cited both Curtis and Ravenel as sources of *M. Curtisii* in *Syll. Plant. Crypt.* (1856) is immaterial. In his original description of 1849 he cited Curtis only.

Berkeley gave a specimen of *M. Curtisii* to Phillips, labelled by Curtis, '*Myriangium Curtisii* B. & M. ad Styracem, fine specimens'. That specimen is now in Herb. Mus. Brit., marked by Phillips, '*ex* Herb. Berkeley'. It matches the Curtis specimen in Herb. Montagne which I take as the type, but it cannot be regarded as a cotype, because Curtis was able to name it, thus indicating that it was sent after Montagne's publication of the name.

Miller stated that in the Farlow Herbarium at Harvard there is a Curtis specimen from Tuckerman's herbarium labelled *M. Curtisii* [? by whom], which should be the cotype. The date and locality of that specimen are not given, but it is not a cotype. It has been pointed out on several occasions that the specimens retained by Curtis are not cotypes. Again, on p. 592, under *M. Duriaei*, Miller listed '*M. Curtisii* Berk. & Mont. E. Tuckerman herb. *ex* Michener, Chester, Pa., 1852: 2 specimens (probably cotype of *M. Curtisii*).' But from the date (1852) those cannot be cotypes of *M. Curtisii* and, as shown above, Tuckerman, until at least 1872, regarded all North American specimens as *M. Curtisii*.

Miller concluded that 'as both descriptions [*M. Duriaei* and *M. Curtisii*] fit *M. Duriaei* [*sec.* Miller], and the Curtis and Ravenel specimens named *M. Curtisii* [in America] are in reality *M. Duriaei*, the Ellis name *asterinosporum* becomes the first to be applied to this species'. That seems somewhat obscure. Presumably 'this species' means *M. Curtisii*; in the section on *M. tuberculans*, Miller wrote '*M. Curtisii* (*M. asterinosporum* of this paper)'. But until Miller has examined the Curtis specimen in Montagne's herbarium he is not entitled to assume that *M. Curtisii* is *M. Duriaei*. That Ravenel's specimens are is true, as far as I have seen them, but that is irrelevant.

Myriangium asterinosporum was described by Ellis and Everhart in 1883 as *Cenangium*. Subsequently they decided that it was *Myriangium Duriaei*. Ellis distributed specimens in North American Fungi no. 1279, of which there are two copies in Herb. Kew. Ellis gave the spores as oblong-elliptic or subpyriform, constricted in the middle, three-septate, submuriform, $15–20 \times 6–8\,\mu$. I examined a Kew specimen and found the spores practically the same as Ellis, $16–19 \times 7\,\mu$, and as the stromata were green internally I decided that the fungus was *M. Duriaei*, but with spores smaller than usual. Miller stated that older parts of the Ellis type have spores, $25–34 \times 9–14\,\mu$, and suggested that Ellis and myself gave measurements of immature spores. But these were sufficiently mature to show transverse and longitudinal septa. They may have lacked the full number of septa, but one would not have expected them to become almost double in length

and breadth. It is not clear what Miller means by 'older parts of the Ellis type'—presumably older stromata in other copies of no. 1279. He cited as the type of *M. asterinosporum*, Ellis herb. no. 1279. It is possible that the original collection may have been a mixture, but Ellis and Everhart's description agrees with the specimens distributed to Kew.

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A DAILY CENSUS OF *ALTERNARIA* SPORES CAUGHT FROM THE ATMOSPHERE AT CARDIFF IN 1942 AND 1943

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(With 1 Text-figure)

1. Introduction

It has for some years been apparent to medical men interested in asthma and allied allergic conditions that a study of air-borne mould spores in Britain was much to be desired.

The earliest suggestion that mould spores might be related to respiratory dysfunction in man appears to be contained in an account by Blackley (1873) of how, following the inhalation of *Penicillium* spores, he himself experienced hoarseness and loss of voice going on to 'bronchial catarrh'. He found the involuntary experiment so unpleasant that he did not care to repeat it of his own accord. In spite of this hint, conveyed in a publication that has become a medical classic, the hypothesis that fungus spores were one of the causes of asthma was not definitely formulated until fifty years later, when it was put forward independently by Van Leeuwen (1924) in Holland and Cadham (1924) in Canada. The genus *Alternaria* was first proved to be implicated by Hopkins, Denham and Kesten (1930), who proved beyond doubt that its spores were responsible for attacks of asthma in a man thirty-seven years of age. They showed by measurements of the spores that the species concerned should be placed in Elliott's *A. tenuis* group (Elliott, 1917). Their report was followed by many others, in which not only individual cases but groups of cases of sensitivity to mould spores were described. It is now accepted in the U.S.A. that mould allergy is of considerable importance there though its exact incidence is still in dispute. Reports suggest that it varies considerably in different localities. According to various authorities quoted by Blumstein (1945) from 3 to 42 % of asthmatics are sensitive to moulds. The genus which most frequently causes symptoms is *Alternaria*.

Mould spores regarded as allergens act in exactly the same way as do pollen grains. They are inhaled and their cell contents are absorbed, giving rise, in persons who are sensitive to them, to a chain of reactions resulting in nasal catarrh and asthma or both. Experience has shown that pollinosis (i.e. hay fever proper) is not caused by any and every kind of pollen: it is most commonly due to certain kinds of pollens which occur widely and abundantly in the air. Following Thommen (1931) therefore, who was dealing with pollen allergy, we may postulate certain requirements in regard to those kinds of fungus spores which are likely to cause asthma: they must contain a specific substance (antigen) capable of

evoking an allergic reaction, they must be buoyant and become easily air-borne, they must be produced in large quantities and they must be of wide occurrence. If these postulates are well founded one would anticipate that, while a certain small number of asthmatics might prove to be sensitive to mould spores occurring occasionally in heavy concentration indoors, a great many more would react to spores occurring regularly in heavy concentrations outside. The physician, then, in his search for fungus spores likely to excite allergic reactions, looks to the mycologist for certain information. He needs to know:

(1) What kinds of mould spore are to be found in the air and in what order of abundance.

(2) Whether the commonest types of spores occur constantly throughout the year or are seasonal in their incidence.

(3) How far the seasonal incidence (if any) of these common types of spore varies from year to year.

(4) Whether, and if so to what extent, spore incidence can be correlated with weather conditions.

The physician requires this knowledge primarily for the district in which he is working; he should also have similar data in regard to other areas, so that he may be able to advise his patients on the desirability or otherwise of a change of residence.

2. Study of atmospheric mould spores in America

Extensive studies of mould spores occurring in the atmosphere have been made in the U.S.A. Two methods have been used, sometimes separately, sometimes together, viz. the culture plate method and the gravity slide method.

A. *The culture-plate method*

Petri dishes containing a suitable culture medium are exposed to the air for short periods at intervals throughout the year and the number and types of spores caught are recorded. Usually the time of exposure is so gauged that had it been exceeded more colonies would have developed than could be identified. The intervals between the exposures have varied from daily to bi-monthly.

This method has been used on the most widespread scale by Morrow, Lowe and Prince (1942) on whose behalf plates were exposed bi-monthly for two years at eighteen cities scattered over nine states in the mid-continental region of the U.S.A. They found

(*a*) that mould spores are widely distributed throughout the central and south-western States;

(*b*) that total counts of all mould spores tend to be more uniform throughout the year in the south, but are more seasonal in the north, reaching a peak in the autumn; and

(*c*) that *Alternaria* spores occur more frequently than any other type, *Hormodendrum* coming second in order.

Essentially similar results have been obtained by other workers (Harris, 1942; Blumstein & McReynolds, 1945; Harsh & Allen, 1945). Bernstein and Feinberg (1942), in counts made on plates exposed daily for five years at Chicago, placed *Alternaria* (with 30 % of the total catch) second to *Hormodendrum*; while *Alternaria* counts varied considerably from year to year, they had a marked seasonal tendency, 80 % occurring during the six months June to November inclusive.

B. *The gravity slide method*

This consists in exposing daily for twenty-four hours a glass slide coated with a suitable adhesive; the slide is fixed horizontally in an apparatus by means of which the slide is protected from the weather, but which allows the air to pass freely over it. At the end of the twenty-four hours it is mounted and examined under the microscope, and the spores which have been caught are identified and counted.

This method has been used extensively by Durham (1937, 1938), on whose behalf slides were exposed at sixty-three stations throughout the American Union. The same author (Durham, 1944) has published a tabular summary of the results not only of his own survey but also of other similar observations made throughout North America. He shows that the average seasonal catch on 1·8 sq.cm.* may vary from about 34,000 (in Minnesota) down to fifteen in the Yellowstone National Park and nil in Alaska. High counts (5000 or more) have been obtained at other stations in the Middle West. Counts of between 500 and 1000 were reported from various stations on or near the Atlantic seaboard and relatively low ones (less than 100) in the Pacific States. In general the heaviest incidence was felt during the three months July, August and September, the difference between this period and the rest of the year being more marked in the north than in the south.

It is evident from this brief summary that American studies based on the culture plate method and the gravity slide method both agree that

(*a*) *Alternaria* spores occur with great frequency in the air in U.S.A.;

(*b*) that they are much more abundant in certain regions than in others; and

(*c*) that they exhibit a marked annual periodicity.

3. *Alternaria* spores at Cardiff

(*a*) *The daily census of spores*, 1942–3

No studies of air-borne mould spores such as those described above appear hitherto to have been carried out in this country. From November 1941 down to the present time we have exposed gravity slides daily at Llandough

* This is the horizontal area which in theory should receive in 24 hours a number of spores equal to that contained in one cubic yard of air, on the assumption that the atmospheric spore concentration remains constant and that the air itself is non-turbulent. It is now realized that neither of these conditions is ever likely to be observed in nature, but for the sake of convenience of comparison counts in the U.S.A. are still made on, or stated in terms of, 1·8 sq.cm.

Hospital, Cardiff, primarily to catch pollen. In the present paper we describe the results of counting *Alternaria* spores on the slides which were exposed by us during the years 1942 and 1943 only. The site, the vegetational setting and the general procedure have been described in detail elsewhere (Hyde & Williams, 1944).

Llandough Hospital is situated in the country, at an altitude of 200 ft. $3\frac{1}{2}$ miles from the centre of the city of Cardiff and 2 miles from the Bristol Channel. It is estimated that in 1942 the land within a radius of $1\frac{1}{2}$ miles was utilized as follows:*

	%	%
Grassland	45·5	
Straw crops	20·0	
Other arable land	4·5	
Total cultivable land		70
Woodland		10
Urban and estuarine land		20
		100

In 1943 the acreage under straw crops (then at its war-time peak) probably rose to 22 %. Wheat made up 55 % of the cereal acreage, oats 35 % and barley 10 %.

The procedure may be briefly stated thus: a 3 × 1 in. microscope slide which had been previously coated with a thin covering of melted glycerin jelly was put out every morning at 10 a.m. in an apparatus (situated on the Hospital roof, 22 ft. above ground) which allowed a free flow of air to pass over it but which protected it from rain. After a twenty-four hour exposure the slide was removed and mounted with a $\frac{7}{8}$ in. cover-slip. The whole area (5 sq.cm.) covered by the cover-slip was later examined microscopically.

All the slides exposed during 1942 and 1943 have been examined and the number of *Alternaria* spores seen has been recorded. Those on the 1942 slides have also been measured and co-ordinated.

The identification of our spores as those of *Alternaria* spp. has been based mainly on the descriptions and figures published by Wiltshire (1933). We have submitted some of our gravity slides to Dr Wiltshire. He agrees that the spores which we have entered as *Alternaria* do belong to that genus, though many of them, unlike those of typical *A. tenuis*, do not possess an apical scar. We have also submitted to Dr Wiltshire a preparation made from a culture plate exposed at Llandough on 20 July 1943: he reports that the species concerned is one of the *A. tenuis* group. We have disregarded under-developed and otherwise doubtful spores and our figures are probably conservative.

The results of our daily counts for the two years are summarized, together with data on the average length of the spores caught in 1942, in Table 1, and illustrated graphically in Figs. 1 and 2, in which maximum and minimum temperatures, sunshine, wind and rainfall recorded daily at

* Information on cultivable land from Mr Brynmor Rees, Crops Officer, Glamorgan War Agricultural Executive Committee.

Table 1. Alternaria *spores caught on 5 sq.cm. at Llandough Hospital near Cardiff*

Month	1942			1943	
	No. of spores caught	Maximum no. on one day	Average length of spores (μ)	No. of spores caught	Maximum no. on one day
Jan.	0	—	—	5	3
Feb.	2	1	—	1	1
Mar.	4	2	33·6	1	1
Apr.	17	3	43·3	0	—
May	6	2	47·5	12	6
June	45	5	46·1	24	6
July	148	24	49·0	209	29
Aug.	330	60	45·5 (of 300)	377	62
Sept.	123	31	48·5	116	41
Oct.	34	11	50·5	4	1
Nov.	10	3	38·9	0	—
Dec.	6	2	46·0	0	—
Total	725	—	—	749	—

Penylan, Cardiff have also been entered.* The two curves are essentially similar and in fact the broad agreement between them is remarkably close. They appear to show:

(1) that *Alternaria* spores form a normal and regular part of the annual spore rain at Cardiff;

(2) that while they are virtually absent during the late autumn and winter months, they are present in the spring and summer and in greatest numbers during the months June–September inclusive: the catch during these months totalled 646 spores (89 % of the total) in 1942 and 726 (96·5 %) in 1943;

(3) that the period of highest incidence (June–August) coincides with that of the highest mean temperature; and

(4) that the catch during June–August varies very greatly from day to day. Probably these oscillations are connected in some way with the weather though the exact relationships are not obvious.

(*a*) There is some correlation, though an incomplete one, between daily catch and maximum temperature.

(*b*) There is no apparent correlation between wind velocity and *Alternaria* catch.

(*c*) Rainfall on certain occasions seems to have resulted in a marked though temporary diminution in the catch, e.g. on 21–22 August 1943.

It should be added that the rapid falling off in the catch during September may be due (as is suggested below) less to the effect of falling temperature on rate of spore production than to removal of the substrate on which the fungus mainly flourishes.

A comparison of our figures with those in Durham's table (Durham, 1944) shows that the rate of deposition of *Alternaria* spores at Llandough is

* The weather records, which have been supplied by the courtesy of the City of Cardiff Public Health Department, were made at the Meteorological Station, Penylan, which is situated at 202 ft. about 4¼ miles north-north-east of Llandough Hospital.

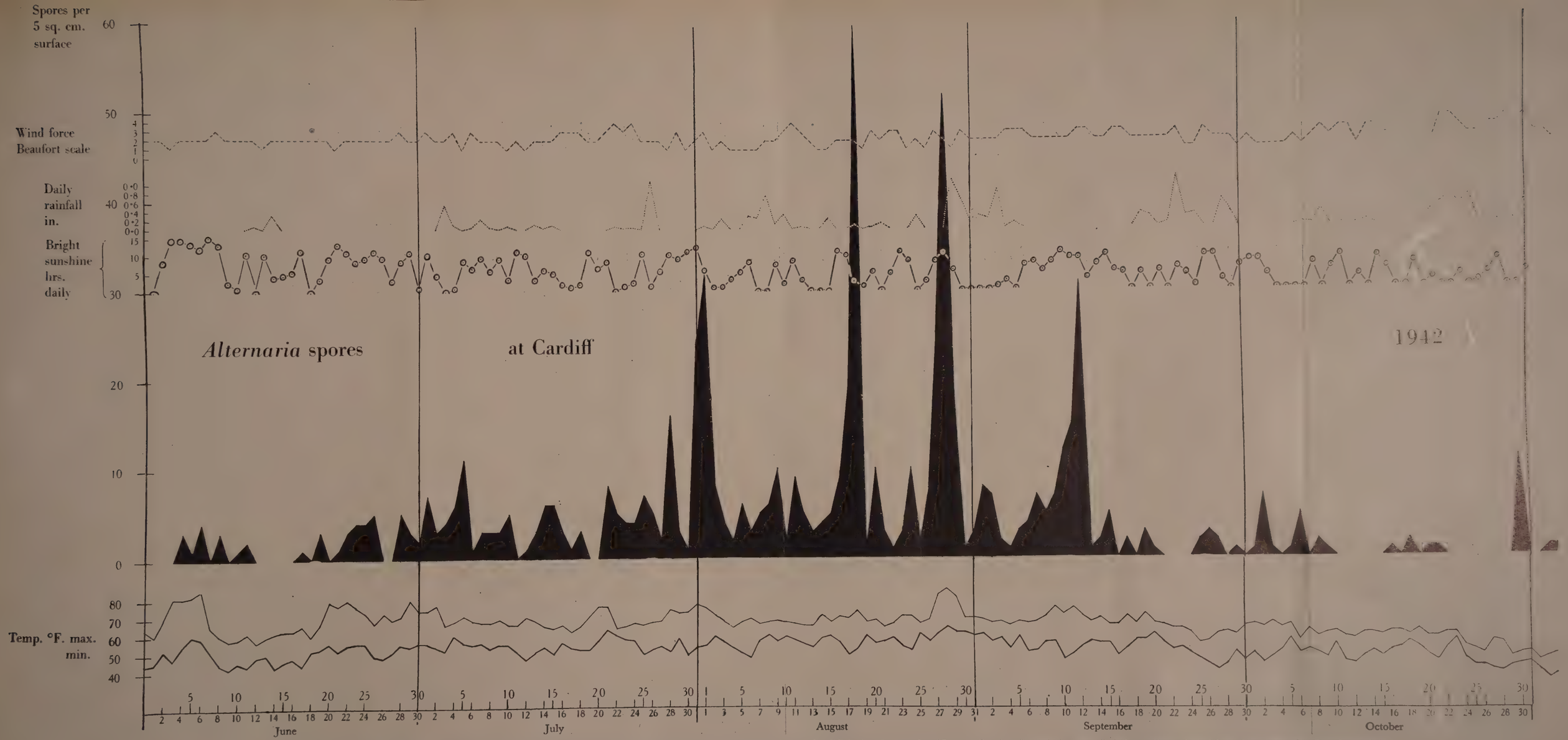

Fig. 1. Graphs showing (*a*) the day-to-day variation in the rate of deposition of *Alternaria* spores at Llandough near Cardiff during the months of June to October (inclusive) 1942, (*b*) daily readings of wind force (as measured in Beaufort units) observed at 09·00 hr. G.M.T. (barred lines), (*c*) daily rainfall (dotted lines), (*d*) hours of bright sunshine (linked circles), (*e*) maximum and minimum temperatures (continuous lines). For further explanation see text.

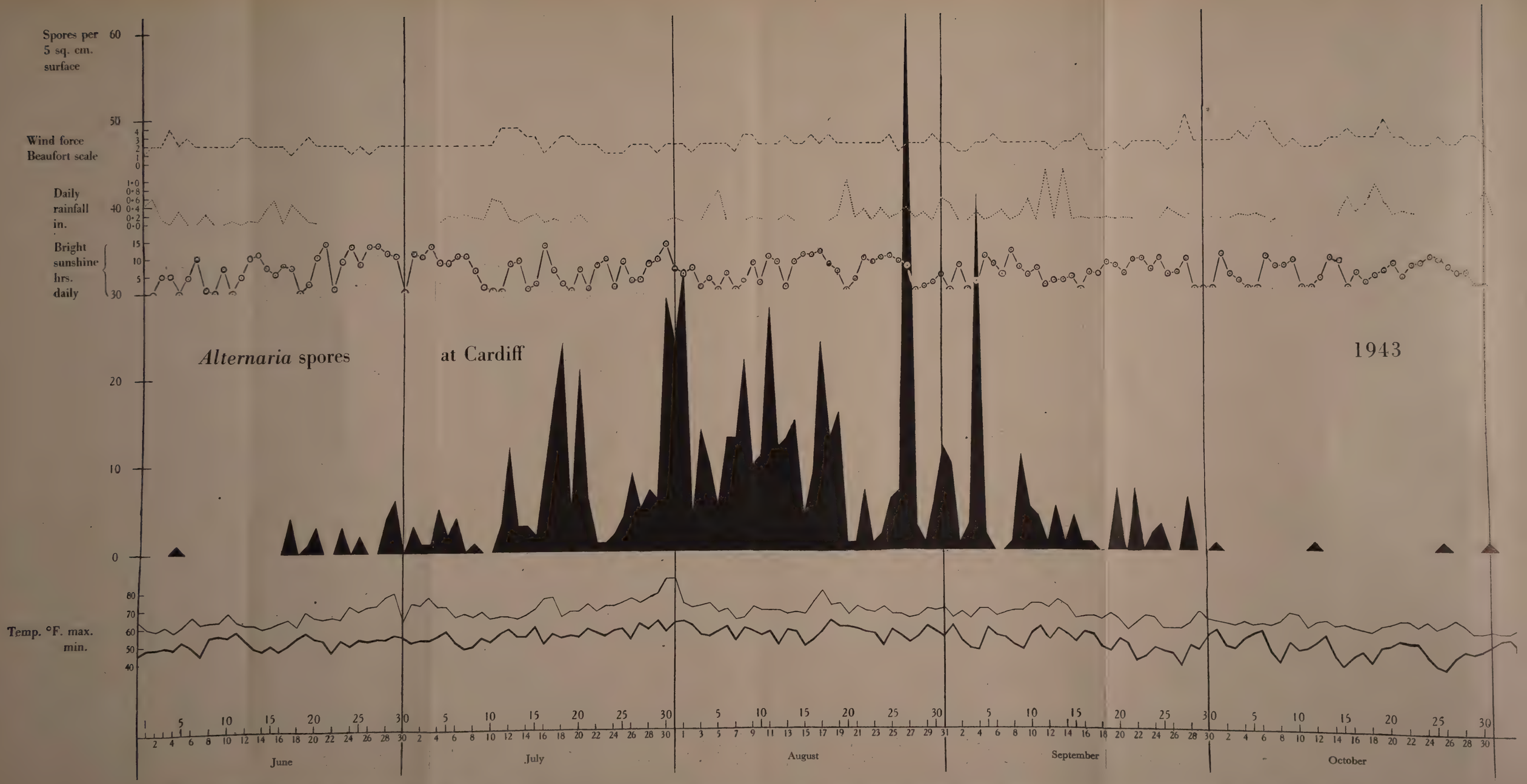

Fig. 2. Graphs showing day to day variation in the rate of deposition of *Alternaria* spores at Llandough near Cardiff during the months of June to October (inclusive) 1943 and changes in weather conditions during the same period. For further explanation see text.

comparable with that at certain stations in the eastern U.S.A. Thus the maximum daily catch and average seasonal total on 1·8 sq.cm.* respectively at the centres named were as follows: Greenville (Maine), 25 and 278; McKeever (N.Y.), 21 and 350; Yorke (Maine), 16 and 202; as compared with Llandough (Wales), 22 and 255.

(*b*) *The probable source of supply of the spores*

Mortensen many years ago (1910) noted *Alternaria* as being common in Denmark on moist straw of *Avena*, *Triticum* and *Hordeum* (Lind, 1913, p. 536).† Durham (1938) remarked that the straw of wheat and other cereals seems to form an ideal culture medium for *Alternaria*, and thought that the varying incidence of its spores in the U.S.A. both in time and space could thus be accounted for. Ogilvie (1943) reported that the blackening of wheat ears, 'a common and well-known trouble in the western province' (i.e. in the west of England) was due *inter alia* to *Alternaria* spp., which, he informed us, occur very commonly on wheat so affected. As already stated, about 20% of the land within 1½ miles of Llandough Hospital was under straw crops, largely wheat, in 1942–3. Blackening of wheat ears was very prevalent in the area around Llandough in both the seasons concerned‡ and, furthermore, the date of completion of the wheat harvest (early October in both years) coincided closely with the almost complete disappearance of *Alternaria* from our slides in each of the two years.

We have no means of confirming directly the prevalence of *Alternaria* on wheat at Llandough during 1942 and 1943, but that it does so occur locally is proved by observations made by us in 1945. We exposed prepared slides during threshing operations at Llandough Farm (Mr Thomas, ½ mile from the Hospital) on 2–3 November 1945 and at Ynyston Farm, Leckwith (Mr Coles, one mile from the Hospital) on 31 December 1945. The slides were so placed as to catch the greatest possible amount of dust from the machinery; they were exposed for periods varying from four to twenty minutes. The catch per minute on 5 sq.cm. on 2–3 November, from a stack of Wilhelmina wheat, varied from twelve to eighty-seven *Alternaria* spores (nine slides in all, average thirty-two per minute), that on 31 December, from a stack of Bersée wheat, amounted to seven and nine per minute respectively on the two slides exposed.

The occurrence of *Alternaria* spores on the slides we exposed in 1942 and 1943 might therefore be explained on the hypothesis that they were formed in and liberated from wheat and other cereal fields around the Hospital. That they should have been derived from local sources is what in general we should expect from our work on atmospheric pollen: a daily catch of fifty grains or more of a particular type on 5 sq.cm. can usually though not always be related to a probable source within a mile of the observation station.

* See footnote, p. 80.
† We are indebted for this reference to Mr John Rees.
‡ Information from Mr Brynmor Rees, Crops Officer.

4. *Alternaria* spores in relation to allergy

We do not at present know to what extent our findings apply outside the Cardiff area. We hope later, by the help of slides which during the past few years have been exposed for us in various parts of Great Britain, to extend our observations. In the meantime it is clear that around Cardiff at certain times the atmospheric concentration of *Alternaria* spores is sufficiently high to create a presumption that *Alternaria*-spore allergy exists among the human population, and that catarrhal or asthmatic attacks occurring either during the late summer, especially near wheat fields, or at any other time near the scene of wheat threshing, may fairly be suspected of having some such origin.

5. Summary

1. The daily incidence of *Alternaria* spores at Cardiff in 1942 and 1943, as determined by counts made on gravity slides, is described.

2. It is shown that, during the two years concerned, the deposition of *Alternaria* spores was virtually confined to the period June to September inclusive.

3. The relation of *Alternaria*-spore incidence to various atmospheric factors is illustrated diagrammatically and briefly discussed.

4. The provisional hypothesis is advanced that the *Alternaria* spores caught at Llandough originated mainly on cereals growing in the vicinity.

We desire to thank Dr D. G. Morgan (Medical Superintendent, Llandough Hospital) for his personal encouragement of this investigation.

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NATURAL OCCURRENCE OF SPROUTING OF THE ASCOSPORES OF *SPHAERULINA MAPPIAE* (PETCH) N.COMB., IN CEYLON

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(With Plate IV)

Description

The fungus under consideration, originally described as *Sphaerella mappiae* Petch (1922), is a little-known species causing a leaf-spot of the shrub *Mappia ovata* Miers in Ceylon. This host occurs sparingly on the Tea Research Institute's estate,* and two or three plants, kept under observation for more than a year, have remained continuously and very heavily infected over the whole period.

The symptoms (Pl. IV, fig. 1) are striking. Petch (1922) briefly describes the spots as 'pale brown, circular, up to 2 cm. diameter, often irregularly zoned'; in the fresh condition, however, a bizarre effect is produced by the differences in colour between successive zones and their irregular juxtaposition, many of the zones being incomplete. The centre of the spot is almost white, with the surrounding zones of successively darker shades of brown. The zones are separated from one another by slightly raised, wavy margins; the outermost impinges directly on the unaltered green tissues, or there may be a narrow, purplish border. The differences in colour are most pronounced on the upper surface.

The perithecia are entirely hypophyllous, crowded but quite separate, immersed, erumpent, averaging about 125 μ in diameter. The asci (Pl. IV, fig. 2) are clavate, 50 μ or more in length, and contain eight biseriate spores. The latter, while still within the ascus, though ripe in appearance and readily extruded in water, are entirely uniseptate. A sample of twenty-five ascospores, in this condition, measured 15·5–21·0 by 2·5–4·0 μ, with a mean of 17·9 $\pm$ 0·3 by 3·7 $\pm$ 0·1 μ. The spores are straight or slightly curved, usually somewhat clavate with the lower cell narrower and more pointed than the upper. The septum, which is marked by a slight constriction, is almost invariably median.

The characters described so far agree sufficiently well with Petch's (1922) diagnosis of *Sphaerella mappiae*, while examination of the type material, Herb. Perad. 5236, although unfortunately revealing immature asci only, with no spores, confirmed the specific identity of the two collections. The chief interest, in the present instance, lies in the further development of the ascospores. In the field, in the early part of 1944 and again in 1945, in both cases during a period of dry weather, most infected leaves bore extruded spore masses adhering *in situ* around the emergent ostioles. The masses

* Near Talawakelle, C.P., elevation *c.* 4500 ft.

were yellowish, firm and coherent in texture, not easily manipulated without crushing. They were found (Pl. IV, fig. 3) to consist of enlarged, two-, three-, and four-celled ascospores with very numerous sprout cells produced terminally and laterally by the constriction of a narrow sterigma or neck. The sprout cells are bacillar, oblong or somewhat narrower below, straight or very slightly curved, apparently biguttulate later, in size 4·5–7·0 by 1·5–2·5 μ with a mean (25) of $5{\cdot}4 \pm 0{\cdot}14$ by $2{\cdot}0 \pm 0{\cdot}05\,\mu$. Their adhesion in a compact mass with the original ascospores indicates that they are classifiable (Mason, 1937) as 'slimy radula spores'. They were not observed to germinate. The associated ascospores varied in size from 14·5–30·5 by 3·5–6·5 μ with a mean (50) of $22{\cdot}3 \pm 0{\cdot}5$ by $5{\cdot}2 \pm 0{\cdot}03\,\mu$. One or both of the original cells may be enlarged, and septate, the additional cross walls not being associated with any constriction. The production of sprout cells is not confined to the spores which have become multiseptate nor, apparently, is it necessarily an immediate consequence of this condition. In water, the ascospores in all conditions have been observed to germinate only by the production of apical germ tubes; presumably, the budding process takes place in moist air, as is suggested also by the increase in size and abundance of the adherent spore masses on leaves placed in a moist chamber.

Discussion

The production of sprout cells and other instances of 'fructificative germination' (Brefeld, 1891) in ascospores was a favourite subject of investigation among the earlier authors. It is well known to occur in the yeasts, in the Taphrinales and certain Hypocreales (de Bary, 1887), and in such forms as *Plowrightia* (*Dothidella*) *ribesia* for which Hoggan (1924) investigated the possibility of a connexion with *Dematium pullulans*. It was reported in the Erysiphales by Paunero Ruiz (1927). Generally, however, it has received scant attention from later writers, particularly in the group to which the present species belongs, namely, the Sphaeriales, and 'Mycosphaerellaceae' in particular. Bertus (1927) described a rather unusual instance of the abscission of conidia from the ascospores of *Glomerella piperata* in Ceylon, but the best-known example is that of *Sphaerulina intermixta* described and illustrated by Brefeld (1891). (For modern views on the nomenclature of the fungus, see Bisby and Mason, 1940.) Brefeld's account, with his figure, is reproduced by Gäumann (1926) and, with some reserve, by Gäumann and Dodge (1928). The condition is identical with that now described, from nature, for the fungus on *Mappia ovata* and it is interesting to find the original observation vindicated.

The biological significance of the phenomenon cannot profitably be discussed in the absence of experimental data. But the very heavy degree of infection invariably encountered with the *Mappia* leaf-spot suggests that the sprout cells are an important and effective means of dispersal.

There remains the question of the generic position of the present species, namely, whether the eventually multiseptate condition of the ascospores warrants a transfer from *Sphaerella* Ces. & deNot. to *Sphaerulina* Sacc. That it does so would seem to be in accordance with accepted tradition. More-

over, while I have found no evidence in the literature for the development of additional septa in the ascospores of *Sphaerella* (incl. *Mycosphaerella*) spp., there has been no lack of evidence for the long persistence of the uniseptate condition in *Sphaerulina*. *S. taxi* Massee (1915) will probably be the most familiar example (Callen, 1938); at least seven other species can be included on the basis of their diagnoses in Saccardo. Finally, the budding of the ascospores can itself corroborate the proposed transfer in that the process as here described appears to be unknown in other species of *Sphaerella*, for which genus Brefeld (1891) instances a quite distinct type of 'fructificative germination' leading to the formation of *Hormodendron*-like chains of relatively large, acropetal spores (Pl. IV, fig. 4) which are evidently thallospores in the sense of Mason (1937). As already indicated, I am satisfied as to the specific identity of the present fungus with the type of *Sphaerella mappiae* Petch. Accordingly, the transfer to *Sphaerulina* necessitates a new combination, which is now formally proposed. On the basis of the additional information now available, the diagnosis of the species (in English originally) is amended and a new collection, showing the *Sphaerulina* condition, is specified as a homoeotype. In the amended diagnosis, the writer's additions are printed in italics:

Sphaerulina mappiae (Petch) Bond, *n.comb.*

Sphaerella mappiae Petch, *Ann. R. bot. Gard., Peradeniya*, VII, 303 (1922)

'Spots pale brown, circular, up to 2 cm. diameter, often irregularly *and prominently* zoned. Perithecia hypophyllous, crowded, immersed, about 0·1 mm. diameter. Asci clavate, narrowed above, thick-walled, almost sessile, spores biseriate, 36–40 × 12–14 μ, *becoming larger later*; no paraphyses. Spores narrow-oval or fusoid, *becoming somewhat clavate*, hyaline, *at first* one-septate, *later mostly two- to three-septate*, 12–30 × 2·5–6·5 μ, *capable of producing abundant sprout cells*.'

On leaves of *Mappia ovata* Miers, in Ceylon.

Type: Herb. Perad. 5236, Hakgala, April 1917.

Homoeotype: Herb. T.R.I. 350, St Coombs, Talawakelle, Feb. 1944.

Duplicates of the homoeotype have been sent to Peradeniya, New Delhi, and the Imperial Mycological Institute, Kew.

In conclusion, it is worth noting that no conidial stage of this fungus has as yet been detected. *Septogloeum mappiae* Petch (1917), collected originally from the same locality as '*Sphaerella mappiae*', is suggestive in this connexion, but does not appear to occur at St Coombs. Examination of the type of the former species, Herb. Perad. 4730, has revealed no trace of any associated perithecial stage.

Summary

A leaf-spotting fungus identifiable with *Sphaerella mappiae* Petch is described on *Mappia ovata* Miers in Ceylon. In two successive years the perithecia were observed with adherent, extruded spore masses in which the majority of the ascospores had become two- to three-septate and had budded off large numbers of 'sprout cells'. The significance of this be-

Fig. 1.

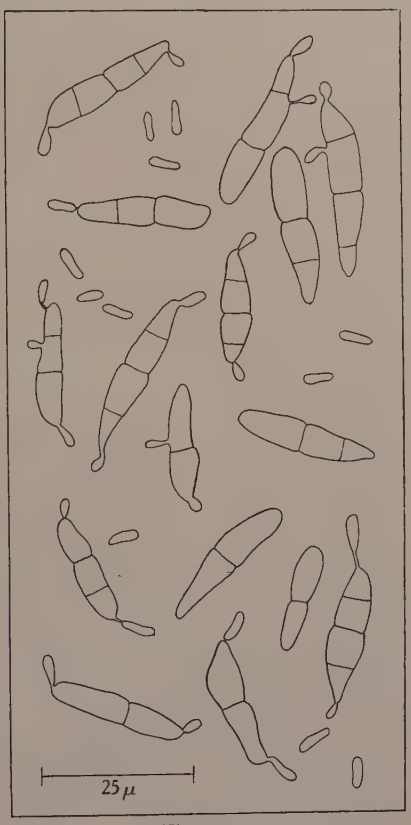

Fig. 3.

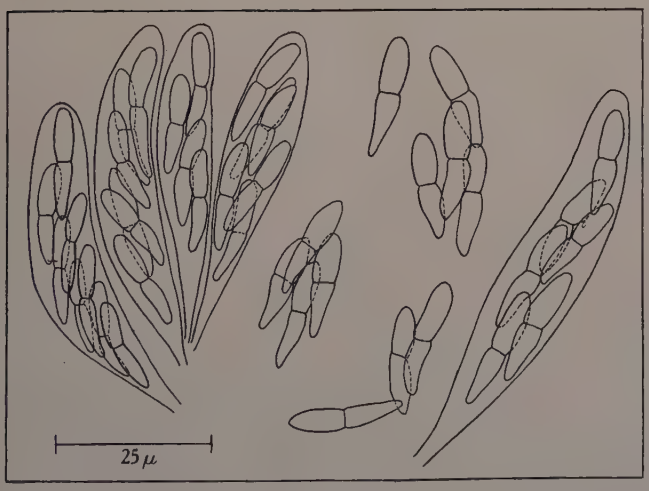

Fig. 2.

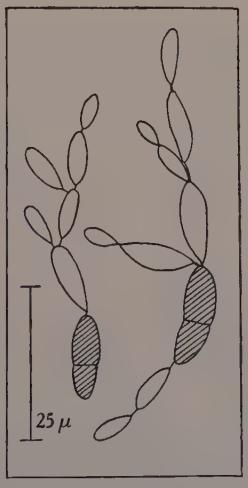

Fig. 4.

haviour is discussed, with the conclusion that the species should be transferred to the genus *Sphaerulina*. The new combination *Sphaerulina mappiae* (Petch) Bond is formally proposed, the diagnosis being slightly amended and a new homoeotype specified. No connexion has been found with the conidial fungus *Septogloeum mappiae* Petch, on the same host.

Grateful acknowledgment is due to Dr S. P. Wiltshire for advice on taxonomy.

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EXPLANATION OF PLATE IV

Fig. 1. Leaf of *Mappia ovata* Miers, showing natural infection by *Sphaerulina mappiae*, ⅔ nat. size. (Photo by C. A. Loos).

Fig. 2. Group of asci and ascospores of *Sphaerulina mappiae* obtained from crushed perithecium, in water. Camera lucida drawing, ×800.

Fig. 3. Mature ascospores and 'sprout cells' of *Sphaerulina mappiae* from extruded spore mass, in water. Camera lucida drawing, ×800.

Fig. 4. Part of Brefeld's (1891) Taf. vi, fig. 38, showing 'fructificative germination' of *Sphaerella punctiformis* ascospores, in moist air. The original spores are hatched. The figure is reproduced at ×800.

(*Accepted for publication* 8 *February* 1946)

NEW AND INTERESTING PLANT DISEASES

By W. C. MOORE, *Plant Pathology Laboratory, Harpenden*

23. Leaf Blotch of *Allium* (*Heterosporium Allii* Ellis & Martin and *H. Allii* var. *cepivorum* Nicholas & Aggery)

Four species or varieties of *Heterosporium* have been described on *Allium*, and two of them have been reported occasionally in England.

Ellis and Martin (1885) erected *H. Allii* for a fungus occurring on *Allium vineale* in North America and gave it the following diagnosis: '*Heterosporium Allii* E. & M.—on withered leaves of *Allium vineale*, Newfield, N.J. Aug. 1883. Hyphae erect, subcontinuous, nodulose, olive-brown, about $50 \times 9\,\mu$. Conidia oblong, fuscous, minutely echinulate, 1–3-septate, $20–33 \times 9\,\mu$. Differs from *H. Ornithogali* in its olivaceous colour and smaller conidia.'

This species has since been reported (Rostrup, 1902 *a*) on shallot (*A. ascalonicum* L.), on garlic (*A. sativum* L.) and (Rostrup, 1902 *b*) on chives (*A. schoenoprasum* L.) in Denmark; on garlic in Moravia (Baudyš, 1930); on leek (*A. Porrum* L.) in Belgium (Marchal, 1938) and Canada (Conners, 1944); on chives in England; on various wild species of *Allium* in the United States (Overholts, 1934; Jacques, 1941); and in soil in India (Chand, 1937). In Rab. *Krypt. Fl.* I, IX, 78, it is recorded also on *A. fistulosum* as well as on *Lilium lanceolatum* and *Tritona uvaria*. There appears to be no record of it on onion (*Allium Cepa* L.). Jørstad (1945) has recently listed *H. Allii* in Norway on the leaves of onion, shallot, leek, chives and *Allium fistulosum*, and *H. Allii-cepae* (syn. *H. Allii* var. *cepivorum*) on the leaves and stems of *Allium fistulosum*.

Briard (1886) found a fungus in France on dead or dying leek leaves, and named it *Heterosporium Ornithogali* Klotsch. var. *Allii Porri* Sacc. & Br., but later the same year Saccardo (*Syll. Fung.* IV, 480) listed it as *H. Allii* var. *Allii-Porri* Sacc. & Br. The conidiophores were torulous, septate, $80–120 \times 8–10\,\mu$, with greyish brown, 1–3 septate conidia $28–44\,\mu$ long and $12–16\,\mu$ broad. The only other record of this variety I have found is one on *Allium* in Pennsylvania in 1929 by Overholts (1934), who gave the spore measurements as $42–66 \times 12–15\,\mu$.

Ranojević (1910) was the first to report a *Heterosporium* on onion. He found it present in grey spots on wilting onion plants in Serbia in June 1905, and named it *H. Allii-Cepae* Ranojević. The conidiophores were up to $198\,\mu$ long and $7{\cdot}5–20\,\mu$ broad. The conidia were either 1-celled, pear-shaped, club-shaped or long elliptical, $32–48 \times 9{\cdot}5–19\,\mu$, or 1–2, occasionally 3-septate and then elongated, straight, often narrower in the middle and pupa-like, $44–76 \times 9{\cdot}5–20\,\mu$ (or even up to $101 \times 25\,\mu$). I am not aware that this species has been reported elsewhere.

Nicholas and Aggéry (1927) also found a *Heterosporium* associated with a leaf disease of onions in France, and called it *H. Allii* Ell. & Mart. var.

cepivorum n.var. They regarded it as distinct from all the known species of *Heterosporium*, including *H. Allii-Cepae*, though I see no good reason for distinguishing it from Ranojević's fungus. *H. Allii* var. *cepivorum* has brown, nodular conidiophores, very occasionally septate, $40 \times 7{\cdot}5$–$10\,\mu$ when young, 90–$115 \times 7{\cdot}5$–$10\,\mu$ when mature, bearing 1–3 conidia. The conidia are cylindrical, unicellular or 1–3-septate, mostly 2-celled, and measure 55–100 (–120) $\times$ 10–$12{\cdot}5\,\mu$.

Occurrence in England. Heterosporium was first noted on *Allium* in Britain in July 1931, when Salmon and Ware (1932) observed a fungus closely agreeing with *H. Allii* var. *cepivorum* on the leaves of five different varieties of onion grown at Whiteparish, near Salisbury. I had an opportunity of examining part of this material. The conidiophores were mostly well within the range given by Nicholas and Aggéry (1927) for *H. Allii* var. *cepivorum*, but a few were over $200\,\mu$ long and distinctly septate. The spore dimensions were 39–110×9–$13\,\mu$, with an average of $81 \times 11\,\mu$ for thirty conidia, and the fungus might therefore equally well have been identified as *H. Allii-Cepae*. The same variety was observed on onion in Devon in 1939 (Moore, 1943), 1943 and 1945, and is evidently not uncommon in West Cornwall and certain parts of Devon, both on autumn- and spring-sown onions.

In September 1934 Dr W. M. Ware sent me some chives from Crowborough, Sussex, the leaves of which were attacked by Rust (*Puccinia Porri* (Sow.) Wint.) and, in addition, showed a species of *Heterosporium*. When examined after keeping the leaves for a day or two in a moist dish, some of the conidiophores of the *Heterosporium* were over $100\,\mu$ long, but though many conidia were measured, none was longer than $38\,\mu$. They were 1–3-septate, with a range of 25–38×8–$12\,\mu$ (Salmon & Ware, 1935). It was therefore concluded that the fungus was distinct from the one observed on onion three years before and agreed more closely with *H. Allii* Ell. & Mart.

The only other known locality for *Heterosporium* on *Allium* in Britain is at Tilgate, Sussex, where Dr J. R. Booer and I found it in June 1945 associated with extensive leaf blotching among some autumn-sown White Lisbon onions growing in an old walled-in garden. One or more elliptical, sunken, pale-brown blotches, up to $1\frac{1}{2}$ in. long and about $\frac{1}{4}$ in. wide, were present on many of the leaves. When young they were clearly defined, but as they became larger, and especially where there were several on the same leaf, all the distal portions of the leaves and the tissues surrounding the blotches became pale, or turned yellow and withered. Condiophores and conidia of *Heterosporium* developed first as a pale, powdery mass in the centre of the blotch and later as a more extensive brown or deep brown mat. The conidiophores were olive-brown, more or less rigid, emerging from the stomata singly or in fascicles of two or three, mostly septate, nodular, slightly swollen at the tip, and measured 90–120×5–$6\,\mu$. The conidia were pale olive-brown, verrucose, and very irregular in size and shape, frequently 1-celled and then usually pear shaped, but mostly 1-septate and straight-cylindrical or with one cell broader than the other, and occasionally 2- or even 3-septate. The measurements of the conidia varied greatly. Thirty-two conidia taken from young blotches showing the pale, powdery mass

averaged 58–16 μ: of these seven were 1-celled with a range of 23–60 × 12–21 μ (average 42 × 16 μ), while the other twenty-five were all 1-septate conidia and measured 45–75 × 11–20 μ (average 62 × 15·5 μ).* The first twenty conidia measured from blotches showing the older brown mat were 37–106 μ long (mostly over 70 μ), with an average length of 74 μ.

Discussion. Jacques (1941), in reporting on his morphological and cultural studies with seven species of *Heterosporium*, said of *H. Allii* Ell. & Mart. that 'the dimensions given in the original diagnosis should not be considered as exact, for it was found in examining the New Jersey material that the length of the conidia exceeds considerably that given by Ellis and Martin'. Jacques gave the dimensions of the conidiophores of this fungus as 19–200 × 5–12 μ, and of the conidia 16–70 × 7–18 μ (averaging 37·3 × 11·6 μ). A dried Petri dish culture of *H. Allii*, collected by Jacques on *Allium vineale* in Illinois in 1939 and preserved in Herb. Kew., shows conidiophores over 100 μ long and conidia up to 60 × 12 μ. There are also in Herb. Kew. two specimens of *H. Allii*, both collected on *Allium oleraceum* on 5 June 1931 from the same locality in Latvia. In one of them, from Herb. K. Starcs, I found no conidia longer than 33 μ; in the other, from Herb. J. Smarods, they were up to 40 × 9 μ and the conidiophores up to 100 μ long.

As pointed out by Jacques (1941), a number of varieties of *H. Allii* have been recorded on a few genera of the Liliaceae and Amaryllidaceae other than *Allium*. Jacques cited var. *Bomareae* Pat. on *Bomarea*, var. *Polygonati* Oud. on *Polygonatum* and var. *Funkiae* on *Funkia*, and regarded retention of these European varieties as unnecessary, on the ground that they differ from the type and from one another 'only in unimportant variations in degree of development due to the environment or to their occurrence on different suscepts'. This view may be justified, for none of the varieties named is described as having conidia more than 50 μ long, but the same is not true of the fungus on onion. Although Jacques found conidia of *H. Allii* up to 70 μ long, the average length was only 37·3 μ, which is less than the average length of even the 1-celled conidia, and considerably less than the average length of the septate and more mature conidia in the material from Tilgate. Moreover, the conidia from chives in this country in 1934 were consistently short. It is true that the spore dimensions of many fungi vary considerably with age and with the atmospheric conditions under which the material is collected, and that spore measurements alone do not always provide a reliable basis for distinguishing between species or even varieties, yet the differences shown in this respect by *Heterosporium* on onion and on other species of *Allium* are so marked as to justify, for the time being, a distinction of varietal rank between *H. Allii* Ell. & Mart. on leek, shallot, chives and garlic, and the form on onion, for which the name *H. Allii* Ell. & Mart. var. *cepivorum* Nicholas & Aggéry is the valid one. *H. Allii-Cepae* Ranojević is considered to be synonymous with *H. Allii* var. *cepivorum*, and *H. Allii* var. *Allii-Porri* with *H. Allii*.

* As most of the conidia were distinctly 'waisted' it should perhaps be made clear that the width measured was invariably the greatest width.

24. Leaf Spot of *Helianthemum vulgare* Gaertn. (*Septoria Chamaecisti* Vestergr.)

In July 1945 Miss J. M. Gooby drew my attention to spotting on the living leaves of certain hybrids of *Helianthemum vulgare* (rock rose) growing in a private garden in Harpenden. The spots were most evident on all plants of a pink variety and were seen also on a narrow-leaved variety with double red flowers, but an adjacent yellow variety was free from them. Most of the spots were not more than 2 mm. in diameter. They were epiphyllous though faintly visible from below, one to many on individual leaves, rounded, reddish-purple or with a pale brown or buff centre, and at times coalescent. Occasionally the spots were as much as 5 mm. in diameter, and then straw-coloured with a narrow purple margin. Similar spots were seen on a few of the sepals.

Pycnidia of a species of *Septoria* were present on a number of the leaf spots: they were very few in number, epiphyllous, sunken and scarcely visible under a lens, 60–90 μ in diameter, with a thin dark brown or blackish wall and no obvious ostiole. The pycnospores were straight or curved, hyaline, rounded at the ends, guttulate, 15–39 × 1·5–3 μ, and doubtfully septate or perhaps with 1–3 septa. The average length of fifty spores was 25 μ. The fungus agreed sufficiently well with the description of *Septoria Chamaecisti* Vestergr. to be identified with that species, which was described on living leaves of *Helianthemum Chamaecistus* Mill. (*H. vulgare*) in Sweden (Vestergren, 1896) and has apparently not been observed elsewhere. *Septoria Helianthemi* Gz. Frag. (*Deuter. Esp.* 1917, 24, Sacc. *Syll. Fung.* xxv (1931), 41) recorded on *H. montanum* in Spain, forms pycnidia with long papillate ostioles on the undersides of the leaves and the spores are much shorter (14 μ), while in *S. Helianthemi* (Vestergr.) Allesch. (Rab. *Krypt. Fl.* 1, 6 (1900), 791), found on rotten, fallen leaves of *Helianthemum* in Sweden, the pycnidia are not produced in spots and the spores are longer (40–60 μ). It is of interest that Grove (*Coelomycetes*, 1, 21) reported finding many *Septoria* spores which 'could hardly be anything else than *Septoria Helianthemi* (Vest.) Allesch.' in pycnidia of *Phyllosticta helianthemicola* Allesch. found on dead leaves, sepals and petals of *Helianthemum* in Ayrshire.

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PROCEEDINGS

Meeting held in the Department of Botany, University College, Cardiff, at 10.30 a.m., 20 October 1945. The President, Mr G. Smith, in the Chair.

The Phycomycete Flora of South Wales

W. R. Ivimey-Cook. Introduction.
Miss E. Morgan. The Saprolegniales.
Mrs E. A. V. Davies. The Pythiaceae.
Miss E. S. L. Jones. The Chytridiales.
Mrs P. E. Perrott. The Monoblepharidales.
Miss W. Davies. The Mucorales.
Discussion.

The Fungus Flora of the Air

R. C. McLean. The aerial Micro-organisms.
D. A. Williams and H. A. Hyde. A daily census of atmospheric *Alternaria* spores at Cardiff during 1942 and part of 1943.

Visit to the National Museum of Wales

Miss E. A. Jenkins and H. A. Hyde. The collection of fungus models in the Department of Botany.

Meeting held at the London School of Hygiene and Tropical Medicine at 2.15 p.m., 16 November 1945. The President, Mr G. Smith, in the Chair.

R. A. Webb. The microbiology of some African native beers.
G. Smith. Introductory talk on an Exhibit of Moulds and Mould Products.

ANNUAL GENERAL MEETING, 1945

The forty-ninth Annual General Meeting was held in the Biology Department, Chelsea Polytechnic at 12 noon on Saturday, 8 December 1945, with the President, Mr G. Smith, in the Chair.

After the Minutes of the previous Annual Meeting had been read and signed the President recorded with deep regret the deaths of three members: Mr M. Barrowcliffe, Mr C. H. Grindling, and Professor H. H. Whetzel.

Reviewing the past year the President said: 'The outstanding events of 1945 have been the terminations of the two wars, with Germany and Japan, and although hostilities in Europe did not end till May, our programme was carried out as planned. Four ordinary meetings were held, one in this room, one at Kew, one at Cardiff, and a fourth at the London School of Hygiene and Tropical Medicine. In addition, there was a very successful two-day Phytopathological meeting at East Malling in July, a meeting held over from the time of the flying bombs of 1944. All who were present will remember the superb organization by the staff of the Research Station—and, possibly, that in 1945 apples ripened a month earlier than usual. The Foray programme was rather more ambitious than last year and included a series of forays on four successive days at Haslemere.

Last year my predecessor drew attention to a Report on the Need for Encouraging the Study of Systematic Mycology in England and Wales, which had been issued and widely circulated by the Council. As a sequel to that Report the Council has this year appointed a sub-committee to enquire into and report on the teaching of mycology in this country. The sub-committee has met several times under the chairmanship of Professor Ingold. A questionnaire was sent out to all heads of Departments of Botany and to members of the Society who are teachers. A large number of replies have been received and analysed, and a report is now in preparation.

Publication of the *Transactions* is still hampered by lack of paper. It is probable that next year's *Transactions* will have to be issued as double numbers but it is hoped that

normal quarterly publication will be resumed in 1947. Arrangements have been made by the Council for the preparation of a much needed supplement to the *Transactions* in the form of a collective index to the first fifty years.

The absence of two familiar names from the list of the Council's nominations for Officers for 1946 will no doubt have been noticed.

Dr Wormald has been an Editor of the *Transactions* for the last sixteen years, and it is with great regret that the Council has, at his request, withdrawn his name from the list of nominations. Dr Wormald is our greatest authority on diseases of fruit and hops, and his wide knowledge of plant pathology has been of the utmost benefit to the Society in his editorial capacity.

The other name which is missing, and yet not missing, from the nominations is that of Dr Ramsbottom, our President-Elect for 1946. Dr Ramsbottom has been General Secretary of the Society for twenty-five years, and in that capacity has given the most ungrudging service. We are fortunate in that his relinquishing the post of General Secretary means only that he will continue to serve the Society in another capacity.'

The Treasurer, Mr A. A. Pearson, then submitted his statement and the accounts were adopted.

The following Officers and Members of the Council for 1946 were elected: *President*, J. Ramsbottom; *Vice-Presidents*, C. T. Ingold and C. Rea, in addition to the two past-Presidents, G. Smith and R. W. Marsh; *Secretary*, G. C. Ainsworth; *Treasurer*, A. A. Pearson; *Editors*, B. Barnes and W. C. Moore; new *Members of the Council*, H. E. Croxall, S. J. Hughes, and F. A. Sawter (to replace Messrs E. A. Ellis, C. T. Ingold and J. H. Western). The Plant Pathology Committee's nominations of D. L. G. Davies, J. Grainger, and I. W. Prentice (to replace Messrs G. R. Bisby, M. H. Moore, and J. H. Western) were agreed to.

The President then moved from the Chair that Dr J. Ramsbottom be elected as an Honorary Member and this was agreed to with acclamation. Dr Ramsbottom briefly replied. Eleven new Members were elected making a total of thirty-two for the year.

After the 1946 programme had been discussed the meeting adjourned until 2 o'clock when the President delivered his address, 'Mycology and the War', after which Dr Barnes moved a vote of thanks to Mr Smith.

G. C. AINSWORTH, *Secretary*

RECEIPTS AND PAYMENTS

for the Year ending 30 June 1945

		£	s.	d.
1944 1 July	Balance brought forward ...	526	3	11
1945 2 June	Sale of *Transactions*:			
	Current Volume	120	15	0
	Back Volumes	81	18	4
	Reprints	67	6	0
30 June	Subscriptions to date ...	325	3	8
	Associates Subscriptions ...	1	0	0
	Gifts to Printing Fund ...	4	0	0
	Bank Interest	1	0	0
	War Loan Interest	23	10	0
		£1150	16	11

		£	s.	d.
1945 2 June	Cambridge University Press: Cost of Vol. XXVII *Transactions*, Reprints, and Common British Plant Diseases	527	4	0
30 June	Postages, Stationery, etc.			
	Secretary	10	10	3
	Sec. Path. Committee ...	3	5	0
	Editor	1	11	10
	Treasurer	3	9	3
	Sundry Printing	24	6	7
	Fees of Meetings	3	1	0
	Hire of Projector	1	10	0
	Subscription to Council for Promotion of Field Studies		5	0
	Balance at Bank	575	14	0
		£1150	16	11

CAPITAL ACCOUNT—*Robinson Bequest* £50, *Cheeseman Fund* £150, *Printing Fund* £500 } *invested in* £255 3½ % *War Stock*. £245 3½ % *War Loan*. £200 3 % *Defence Bonds*.

A. A. PEARSON, Hon. Treasurer

Examined and found correct, E. W. SWANTON

FORAY REPORT, 1945

By the Foray Committee

(G. C. Ainsworth, R. W. G. Dennis, Miss M. P. English,
C. T. Ingold, Mrs E. W. Mason, *Secretary*)

A token Spring Foray was held on Saturday, 12 May, when the Clockcase Plantation, Englefield Green was visited by the Society for the first time in spring. Difficulties of transport and accommodation again made an Autumn Foray on a pre-war scale impossible and the main feature of the season was a series of four day-forays on 14–17 September in the Haslemere district with headquarters at the Haslemere Educational Museum, by kind permission of the Management Committee. Day forays in the London area were also held at Park wood, Ruislip (22 September), East Malling (29 September), Brickett wood (a joint foray with the Hertfordshire Natural History Society) (6 October), Epping Forest (including another visit to the Cuckoo Pits area with the Chingford Branch of the London Natural History Society) (13 October), and Bookham Common (a joint foray with the Ecological Section of the London Natural History Society) (28 October). A Cardiff foray planned for 21 October had to be cancelled because of torrential rain but one enthusiastic member spent some time collecting aquatic Phycomycetes in ponds at Dinas Powis. As in previous years, several natural history societies invited our members to attend their forays.

At the spring foray two areas in the Clockcase Plantation were sampled. In the first, sweet chestnut and birch predominated, and the second was a pure stand of Scots pine. Fine specimens of *Daldinia concentrica* were found on birch in the former area and it was noticed that most of the infected trees had suffered fire injury, possibly the result of a flying bomb which had fallen nearby during the previous summer. Another interesting find on the same day was a medlar tree in the botany garden of the Royal Holloway College showing severe leaf blotch caused by the conidial state of *Sclerotinia Mespili*, the affected tree scenting the whole garden.

Heavy rain severely limited the collecting on the first day of the Haslemere foray and on the other days the effects of the previous dry spell were still apparent. Among the 175 species of larger Basidiomycetes represented in the four days collections were *Inocybe globocystis* Vel. and *I. griseo-lilacina* Lange (which are both new records for Britain), *I. hystrix*, *Cortinarius delibutus*, *C. saniosus*, *C. balaustinus*, *C. damascenus*, *C. bolaris*, a small form of *C. evernius*, a small brown *Telamomium* tentatively identified as *C. penicillatus*, *C. melleopallens*, *Russula gracillina* (see Pearson, *Trans. Brit. mycol. Soc.* XXIII, 308), *Polyporus Schweinitzii* parasitic on cedar, *Sparassis laminosa* (a very large specimen at the foot of a living pine), *Hydnum scrobiculatum*, and *H. graveolens*.

Some interesting Hyphomycetes were also found at Haslemere; *Gonatobotryum fuscum* was found growing abundantly on oak wood cut for firing, and *Zygosporium parasiticum* was isolated from the same wood. The first is a new record for Britain; the second was originally described from Ireland and has been found once in Wales, but not previously in England. Other Hyphomycetes were: *Cordana pauciseptata*, apparently new for Britain, and *Botryosporium longibrachiatum* on dead tomatoes under glass. (The out-of-doors species, usually recorded as *B. pulchrum*, has this year been abundant elsewhere.)

Of Pyrenomycetes, *Ophionectria cerea* was found at Grays Wood again, this time associated with *Anthostoma turgidum* on beech; historically it has usually been recorded as associated with *Diatrype stigma*. *Hypoxylon fuscum* was found for the third time in twenty years, growing on dead birch; every year it is abundant on hazel, and common enough on alder. About a dozen specimens of *Cordyceps capitata* were collected on *Elaphomyces* in Grays Wood and *C. ophioglossoides* was also recorded.

Holt wood at East Malling was again visited and the sweet chestnut plantation was sampled. The general collection was much smaller than in 1944, *Geastrum fimbriatum* and *Clavaria Kunzei* being among the more interesting finds.

A large party worked Brickett wood on 6 October and although agarics were not very plentiful a good and interesting collection of microfungi was made; the day was notable

for the collection, by Mr N. F. Robertson, of perithecia of the oak mildew hitherto unknown in Britain.

The Epping foray gained a certain notoriety in the press from the presence of *Picture Post* photographers. The main party worked the forest between Loughton and High Beech where the collection was laid out and in the afternoon a few additional records were made in the Cuckoo Pits area. *Oidium aureum* was found on beech in the morning.

The foray to Bookham Common on 29 October though late in the season would have proved more fruitful had the weather been kinder. Even so a good display was set out in the waiting room at Bookham station and provisionally named before members moved on to Effingham Junction for tea. A number of very large specimens of *Lycoperdon saccatum* were collected and specimens of *Hygrophorus laetus* and *H. olivaceoalbus* were brought in.

The Foray Committee is greatly indebted to Mr Pearson, Mr Swanton, and Miss Wakefield for making critical determinations of agarics and for checking others, and to Mr E. W. Mason for the note on the Hyphomycetes found at Haslemere.

REVIEWS

Fungicides and their Action. By J. G. Horsfall. (Waltham, Mass.: Chronica Botanica Co.; London: Wm. Dawson & Sons, 1945.) 239 pp. 24 figs. $5.00.

'The writing of this book has constituted for the author a post-graduate course on fungicidal action', writes Dr Horsfall in the preface, and the reader will profit likewise, whether he is on the threshold of a research career or a more experienced scientist responsible for imparting knowledge and inspiration to others.

The book, with a foreword by Dr D. G. Fairchild, is the second of a series of separate memoirs—*Annales Cryptogamici et Phytopathologici*—'devoted to general and systematic cryptogamy and to phytopathology', of which Mr S. D. Garrett's *Root Disease Fungi* was the first. Well documented, and with a bibliography of nearly 500 titles, it shows a confidently critical approach to the literature, which is fairly comprehensively reviewed. There is a general index and an author index.

The first of the sixteen chapters comprises an interesting and useful review of landmarks in the history of fungicides, beginning over two thousand years ago! The second is a necessary prelude to the main body of the work, for it defines the author's general conception of and approach to the problems dealt with in detail later in the book. Thus the reader is early prepared for the stimulation of Dr Horsfall's argument, though he may wish still to debate certain of the issues. Chs. III and IV concern laboratory bio-assay and the statistical treatment of data, subjects that largely provide the warp for the woof of later chapters. 'We are coming rapidly now to a stage where the vagaries of disease control can be studied more thoroughly and accurately in the laboratory than in the field' (p. 18)—conceivable, perhaps, of fungicidal action, but highly controversial of the much wider field of disease control. There is a short section on plant disease measurement in the field from the research angle (pp. 38–41) of special interest to plant pathologists. The principles of plant protection by chemicals are reviewed in Ch. V, and the next four chapters contain a comprehensive dissertation on the factors concerned in the deposition, coverage, and tenacity of fungicides. Recent theories of artificial immunization and chemotherapy receive attention in Ch. X, and the next four deal primarily with chemical problems—the action of copper, of sulphur, and of organic nitrogen and other organic compounds. A chapter on antagonism and synergism in fungicides precedes the concluding one, on Phytotoxicity—perhaps unwittingly a salutary reminder that the host plant may have the final word! Here it may be remarked that the author, by a seemingly unwarranted process of reasoning, arrives at the generalization that 'a fungicide is a chemical to kill plants' (p. 172).

Dr Horsfall adopts a racy, forthright, almost aggressive style throughout, which compels the reader's interest but may generate in some an 'equal and opposite' reaction. His very lively and critical probing of the many and diverse theories of others cannot but

impress, and the liberal use of homely analogy and exposition to enlighten some of the more knotty technical problems makes for easy reading and comprehension. A regrettable intrusion in a scientific work is the free use of parochial slang, most of which is necessarily transient and by many will not be understood.

This is a very useful and stimulating book at a reasonable price, and is a noteworthy addition to the literature because much up-to-date information has been skilfully drawn together from many different sources and arranged as a valuable work of reference. A few errors here and there (e.g. 'illusions', p. 62) do not unduly intrude.

M. H. Moore

Flora Agaricina Danica. By Jakob E. Lange. 5 vols. (Society for the Advancement of Mycology. 23 Rolighedsvej, Copenhagen.)

Although we had heard with deep regret that Jakob Lange had died during the war, we have received with much satisfaction the fifth and last volume of his *magnum opus*. This completes a work written in English which no serious student of the agarics (if he or she can afford it) should be without. It should certainly be in the library of most natural history museums and universities. It is of value to the beginner and the expert. More than a thousand species are described and each one has a coloured figure (or portrait, as the author loved to call them) beautifully drawn and reproduced. The descriptions are brief because most specific details can be seen on the 'portraits' and the author even recommends that they should be examined with a lens. Microscopic features of diagnostic importance with accurate measurements are given, including spores, cystidia and sometimes the cellular structure of the cuticle of the pileus.

On the whole Lange was conservative in his classification. He adopts Quélet's genus *Rhodophyllus* for all the species with pink angular spores, but otherwise there are few departures from the Friesian groupings. Here and there he introduces a new genus, not always with happy results. His idea of some species may need correction, but many others which badly needed an authoritative interpretation will be accepted.

Lange wrote English with great fluency. The writer of this review looked through most of his manuscripts before publication and had many a lively discussion about the English idiom, which had its effect in the final script sent to the printers. The style, however, is his own and is clear and concise.

Flora Agaricina Danica followed the series of twelve brochures which Lange began in 1914 and finished in 1938, under the title 'Studies in the Agarics of Denmark'. They were published in the *Dansk Botanisk Arkiv*. The original object of these booklets was to provide accurate microscopic data for the agarics. The first, which dealt with *Mycena*, made the study of this genus comparatively easy. The others never quite reached the high standard set by the first, but they all had some features that were helpful especially the dichotomous keys to species. When Part 6 was reached dealing with Russula and Psalliota he found it necessary to do more than give microscopic data. In this and subsequent parts, he included short descriptions of each species. But these booklets were intended only to be used in conjunction with his water-colour drawings which were in the library of the Botanic Garden, Copenhagen, and therefore only available to the few. At last he was offered sufficient support to allow a wider public to take advantage of his admirable 'portraits'. The financial risk must have been considerable, but was sponsored by various Danish scientific societies and the first volume issued in 1935. When the war came, there was still one volume to appear. The author was spared to see it completed in 1941, and he died early in 1942.

Jakob Lange was well known as an authority on agriculture. He had been for many years the principal of the Small Holders' School. Mycology was a pastime; but one to which he brought all the keenness and powers of observation that had served him and others so well in his professional career. The occupation of his country by the German army was a hard blow. In the words of his son: 'he always loved freedom and hated nazism. In the last years of the occupation, his old home, the Small Holders' School, was taken over by the Gestapo and they made it the worst prison in the whole country. At last it was completely destroyed by the R.A.F.'

It was perhaps fortunate that he did not live to see this. A more enduring monument than the school is this work which he has bequeathed to future mycologists.

A. A. Pearson

Die Hefesammlung des 'Centraalbureau voor Schimmelcultures'. Beiträge zu einer Monographie der Hefearten. II. Teil. Die anaskosporogenen Hefen. Zweite Hälfte. By H. A. Diddens and J. Lodder. (Amsterdam: N. V. Noord-Hollandsche Uitgevers Maatschappij, 1942) xii+511 pp., 99 figs.

The monographic survey of the yeasts, based on the investigation of the extensive collection at Baarn, and already well known to mycologists by the volumes issued in 1931 (N. M. Stelling-Dekker, *Die sporogenen Hefen*) and 1934 (J. Lodder, *Die anaskosporogenen Hefen*, Erste Hälfte), is continued in a third volume published in 1942, and now becoming generally available with the liberation of Holland.

This volume describes the three genera referred to the Mycotoruloideae, a subfamily of the Torulopsidaceae. It begins with an account of the characteristics and systematics of the subfamily, and of the materials and methods used by the authors. The main part of the book, occupying nearly 400 pages, contains an exhaustive description of the three genera (*Candida* with twenty-five species of which seven are new, and eight new varieties; *Brettanomyces* with four species; and *Trichosporon* with six species including two new species and two new varieties). A summary of the work, Latin diagnoses of the genera as amended by the authors and of the new species and varieties, with comprehensive indexes of authors and of systematic names, complete the work.

In the preparation of the book, 288 distinct stocks of *Candida*, seventeen of *Brettanomyces* and forty-three of *Trichosporon*, were used. Full details of the sources of these stocks are listed. The long lists of synonyms and the critical discussions of the opinions of other investigators of these fungi show that Diddens and Lodder have drawn upon every available source of information in forming their own conclusions. The great amount of research which has gone to the making of the book establishes the book as one of outstanding authority.

Many of the species described, especially of *Candida* and *Trichosporon* have been prominent for years past as pathogens of men and animals. To the ordinary mycologists, many of these species have been puzzles, the more so as the various authors who have concerned themselves with these fungi have often used methods more familiar perhaps to bacteriologists than to mycologists. Much of the earlier work does not fit into the traditional framework of mycology with its morphological bias, for these fungi are not well dowered with morphological characters on which separations can be made. Diddens and Lodder have now established the importance of physiological differences in determining the systematic status of the members of the Mycotoruloideae. They have done much to drive a path through a hitherto trackless waste of synonyms and of uncoordinated observations and to open up that forbidding subject often called medical mycology. It is on this account particularly that the book is very welcome. With this and the preceding monographs we can form a much more satisfying picture of the yeasts and it is to be hoped that we may have in due time an English version of the whole of the work. These monographs from Baarn should do much to attract more workers into a field of mycology where still there are harvests to gather.

Warm congratulations are due to the authors, and to the Centraalbureau voor Schimmelcultures, for finishing and issuing the volume at a time when Holland was occupied by the enemy and when there must have been many hindrances, material and spiritual, to the prosecution of work of the kind. It is to be hoped that the Centraalbureau will continue to use its collections as a means of providing surveys, not only of the yeasts, but of other groups of fungi to which clear guides are still needed.

B. Barnes

NOTICE

List of Common British Plant Diseases. A photographic reprint of the list is now available, price 5*s.* net (postage 3*d.*), and may be obtained from the Cambridge University Press.—Eds.